CMC 2006

Concept Maps:
Theory, Methodology, Technology

Proceedings of the
Second International Conference
on Concept Mapping

Alberto J. Cañas
Joseph D. Novak
Editors

Universidad de Costa Rica

2

Segundo Congreso Internacional
sobre Mapas Conceptuales
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Volume I

Alberto J. Cañas, Joseph D. Novak, editors

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Preface

Welcome to CMC 2006, the Second International Conference on Concept Mapping and to San José.

Following on an exciting conference in Pamplona in 2004, CMC 2006 is the second time that the concept mapping community from around the world gets together to share research and experiences. We are enthusiastic about the variety of topics covered in the conference, and the broad representation from education, government and industry.

The program and these proceedings are the product of the collaboration and hard work of a number of collaborators. We are fortunate to work with a great group of committee members, who had to work overtime given the unexpected large number of submissions, reaching over 250. The Program Committee had a difficult time selecting those that would be presented orally and as posters, while keeping the number of oral presentations within a reasonable number that would allow for simultaneous translation. Many thanks to the authors without whose contribution these proceedings would not have existed.

In addition, we are pleased to have outstanding invited speakers: Joseph D. Novak, Gaspar Tarté and Pat Hayes. A selected set of panels complement the program with discussions from key personnel in the concept mapping community.

The Local Organization Committee has done and outstanding job at taking care of all details to make the participants feel at home, and the Universidad de Costa Rica has gone out of its way to make sure the Conference is a success. Finally, we thank the sponsors whose support was crucial in making the Conference a reality.

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A PROPOSAL TO REFINE CONCEPT MAPPING FOR EFFECTIVE SCIENCE LEARNING

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Abstract. Concept maps are found to be useful in eliciting knowledge, meaningful learning, evaluation of understanding and in studying the nature of changes taking place during cognitive development, particularly in the classroom. Several experts have claimed the effectiveness of this tool for learning science. We agree with the claim, but the effectiveness will improve only if we gradually introduce a certain amount of discipline in constructing the maps. The discipline is warranted, we argue, because science thrives to be an unambiguous and rigorously structured body of knowledge. Since learning science may be seen as a process where a novice is expected to be transformed into an expert, we use the context of learning science for making the proposal. Further, we identify certain anomalies in the evaluation of concept maps, and suggest that the evaluation should be based on semantics of the linking words (relation types) and not on graphical criteria alone.

1 Introduction

Concept maps are two-dimensional graphical representation of one's knowledge of a domain (Novak & Gowin, 1984), based on Ausubel's theory of meaningful learning in the classroom (Ausubel et al., 1978). Over the past three decades, the tool has been used in research studies for depicting and evaluation of knowledge. Though it was mostly used by researchers in education, often it has also been used in other domains, such as, business management. In this paper, we look at the use of concept maps in science education, and point out certain problems in their use. However, we suggest, if the method of making and evaluating the maps is modified, then it can become a very effective tool for learning as well as for evaluation.

Concept maps are used affectively for knowledge elicitation in research studies for meaningful learning, for recording the changes taking place during instruction, for recording conceptual change in longitudinal as well as cross-age studies, for mapping the differences in knowledge structuring between experts and novices. In a review study based on about 150 studies on concept mapping, the authors conclude that concept mapping helps students gain meaningful learning, and enhance the integration and retention of knowledge (Mintzes et. al., 1997, pg. 428). These conclusions are based on the use of the mapping technique for recording the changes before and after instruction. By comparing successive concept maps researchers documented and explored the conceptual change in a group of biology students as they gained mastery of the domain (Carey, 1986; Wallace & Mintzes, 1990). The studies indicate a change in the use of more number of critical concepts and propositions, more intricate hierarchical structure, branching patterns and occurrence of cross-linkages (Wallace & Mintzes, 1990, pg. 1038). Concept maps are used to depict expert-novice differences in knowledge structures on the basis of the frequency of concept descriptors and propositions that appear in a map (Mintzes, in press). Longitudinal studies on students' understanding of the particulate nature of matter (from grade 2 to 12) were conducted using concept maps (Mintzes et. al., 1998). The maps revealed students' knowledge structures over a period of time and the maps served to record the changes in their conceptual framework. Thus, concept mapping has been a very useful tool to elicit subjects' understanding and to study the nature of restructuring in cognitive development, particularly in the classroom context.

Our research employed the concept mapping technique for studying the structure and dynamics of knowledge, particularly of conceptual change in science. We noticed that the technique needed some refinements in order to make it more effective for science education. We felt that the existing specifications of the technique are unsuitable for science education, though the tool itself is eminently suitable. Hence we sought to identify the issues as carefully as possible, and we now bring them to the notice of the concept mapping community. Before we exemplify and discuss the problems, it is apt here to mention a set of assumptions that drove us to the conclusions reported here.

Science is a pursuit that *extends* our knowledge gained through folklore, and also *transcends* folklore. The transition from folklore to science is known to be a revolutionary cognitive change. Whether it is from Ptolemy to Copernicus, Aristotle to Galileo, Alchemy to Chemistry, or Natural History to Modern Biology, each of these remarkable changes is a fertile domain of research in the history and philosophy of science (Kuhn, 1962; Thagard, 1992). Paul Thagard, used concept maps to show the differences between the conceptual schemes before and after such transitions. Recently, such studies have also attracted serious attention from developmental psychologists as

well as educationists (Carey, 1986; Nersessian, 1998; Vosniadou & Ioannides, 1998). The nature and dynamics of these transitions are still an active area of research, and obtaining at this stage a unitary picture of this discourse is very difficult. However, there are a few characteristics that distinguish the knowledge representation before and after such transitions. Since these characteristics have a bearing on the discussion that follows, we state them briefly here.

Folklore, though not devoid of abstractions, is less abstract than scientific knowledge. Folklore depends on *implicit* meaning gained mostly by *use*, while the terms used in scientific language thrive to gain their meaning from *explicit definitions,* mostly by operational definitions. Folklore tolerates ambiguous usage of terms, while scientific terms being well defined are least ambiguous. Scientific language also tends to be parsimonious. The objective of this paper is not to argue in favor of these assumptions, we proceed assuming their validity (Nagarjuna, working paper). If we assume that science tends to be the least ambiguous and the most explicit body of knowledge, then we expect that during science education when students are undergoing a cognitive transition from folk language to scientific language, there occurs a process of redefining and re-representing knowledge structures. If we assume that the objective of science education is to help in this restructuring, then we need to identify some methodological principles that will drive such a transition. Though we agree that the fuller context of the transition from folklore to science is too complex, we can at least begin to identify some of the principles. Based on these, we can suggest some refinements in concept mapping methodology. The objective of this paper is to point out some refinements based on the assumptions outlined above.

The strategy is to take few examples of concept maps from the literature, and point out the problems in their evaluation. Therefore we will be conducting the discussion centered around the scoring of the maps and in the process identify the problems. Traditionally, concept maps are evaluated for *structural complexity* and *propositional validity*. While scoring the concept maps, various elements – *concepts, propositions, hierarchy, branching, cross-links* – are assigned scores. The Novakian scoring model is the most widely used (Novak & Gowin, 1984, pg. 37) for evaluating concept maps, though some researchers have further modified the Novakian scoring rubric (Arnaudin et. al., 1984; Markham et. al., 1994; Wallace & Mintzes, 1990). According to the modified rubric, each proposition represented in a map is assigned a score of 1 if the concepts are linked via the linking words. Each level in a hierarchy is given a higher score of 5, because it represents *subsumption*, and a branch is assigned a score of 1 point for the first branch and 3 points for the successive branches, because it represents *progressive differentiation*. Cross-links showing valid relationships between two distinct segments of the map are assigned the highest score of 10 points, because it represents *integrative reconciliation*. Examples are assigned a score of 1 if these are used via the linking word `e.g.' and are placed at the terminal end of the concept map. Informed readers will realize that according to Ausubel, meaningful learning occurs in the form of *subsumption, progressive differentiation* and *integrative reconciliation* (Ausubel et. al., 1978). These measures do capture the nature of knowledge structures, however, we shall show how this measure is insufficient for a comprehensive appraisal of the cognitive restructuring that happens in the context of learning science.

In what follows, we begin by identifying how the existing rubric is inefficient in capturing and comparing the knowledge structures of novices and experts. In the process we also propose refinements, so that concept mapping can be used as an efficient tool for teaching, learning and assessment.

2 Problems in Measuring Cognitive Restructuring During Learning

A comment on the style of presentation in this section is relevant here. We shall take concept maps drawn by a student S1 and compare them with those drawn by S2 who is closer to the knowledge structure of an expert. The maps of S1 are shown on the left and the maps of S2 on the right. The concept maps were redrawn using CmapTools developed at IHMC (IHMC CmapTools, 2004). All maps marked S1 are taken from published literature duly cited.

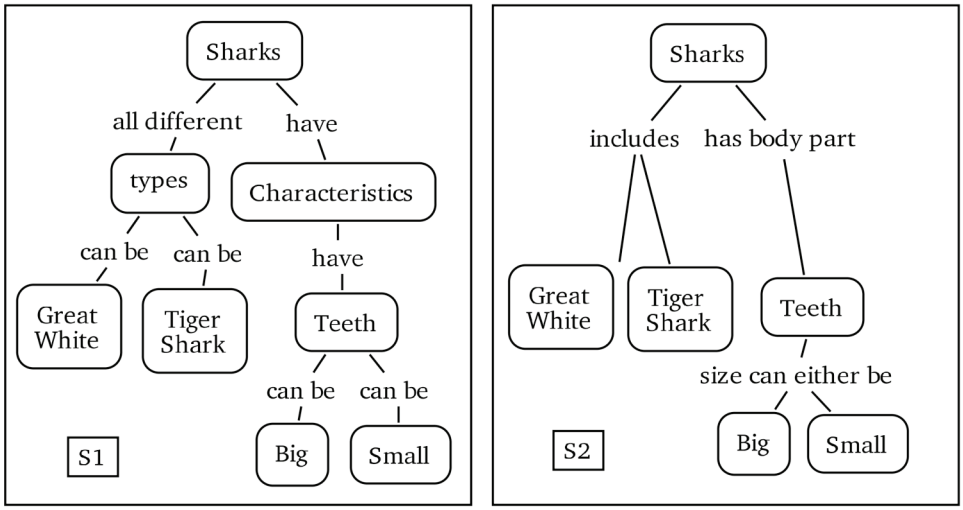


Figure 1. Concept maps on sharks drawn by S1 and S2.

2.1 Accuracy of linking words

Consider the concept maps on sharks (Thompson & Mintzes, 2002) as shown in Figure 1. To indicate the problems related to linking words we have taken the map on the left side from published literature and redrew, and the right side one is made by us. If we use the Novakian scoring method the map drawn by S1 gets a higher score since, the number of nodes (concepts), and the number of propositions are more than in the map by S2. The map of S1 uses the linking phrase "can be" ambiguously: it is used to represent an inclusion relation, and also for possible attributes. The linking phrase "have" is also used ambiguously. The map of S2 is clearly more accurate, and says everything that the map S1 does. This example, illustrates the problem with the rubric, since the map of S2 is closer to an expert, but scores less than the novice's.

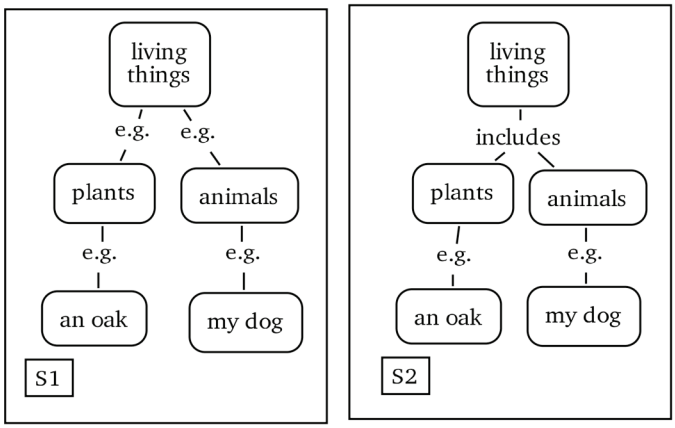


Figure 2. Concept maps on living things drawn by S1 and S2.

In a concept map on water (Novak & Gowin, 1984, pg. 16), shown here as a part of the map, the propositions about living things are depicted as shown in Figure 2. The concept map of S1 is problematic. The map represents correct knowledge, but uses incorrect linking words for the first two propositions. If we grant the map of S1 for the first two relations, S1 and S2 will get the same score. The concept map S1 depicts all propositions by the same linking word `e.g.' represents a `class-subclass' as well as `class-instance' relation. In the Novakian concept mapping methodology, learners are encouraged to anchor examples to the more specific concepts at the terminal end of the concept map by using the linking word `e.g.' (Novak & Gowin, 1984, pg. 16). Example represents the instance of the class, or token of a type. It is very important to realize that this relation is not of subtyping. The relation 'instance-of' is an intransitive relation, whereas the relation `class-subclass' or subtyping is a transitive relation. It

may be noted that the usage of the linking word `e.g.' in the first proposition is imprecise because the actual relation between the concepts should be either `includes', or `subclass-of' or `subtype-of'. The second and third propositions depicts the class-instance relation and hence the linking word `e.g.' is appropriate. This usage is possible only after restructuring due to training. Should not we find a way of giving additional score for such an accurate and explicit use of the linking words displaying more mature representation?

To cite another instance from a concept map on sharks (Thompson & Mintzes, 2002) S1 has a proposition <carnivorous like rays, sharks>, and <sharks have teeth, fins>. S2's map has a proposition <carnivorous includes sharks, rays> and <sharks consists of teeth, fins>. Both the maps of S1 and S2 according to traditional scoring method get equal score. But S2 deserves an extra score because the linking word `includes', and `consists of' depict a mature understanding. The map of S2 carefully distinguishes between the two kinds of inclusion relations (class-subclass and part-whole). Shouldn't we take care of this subtle restructuring that could have happened in S2?

The above examples illustrate that when a novice is becoming an expert, the same domain knowledge gets re-represented by more accurate linking words. Therefore it is necessary to distinguish such a structure from that of a novice, and we should find a way of providing additional score for maps made by S2.

2.2 Validating Hierarchies

Hierarchical organization of knowledge has been appraised as one of the distinguishing characters of scientific knowledge since the time of Plato and Aristotle. Ausubel's theory accommodates for it nicely under *subsumption*. We strongly agree with Novak that meaningful learning proceeds most easily when new concepts or concept meanings are subsumed under broader concepts. More inclusive concepts, should be at the top of the map, with progressively more specific, less inclusive concepts arranged below them. Though, theoretically the points were well taken, in the practice of concept mapping we found some serious anomalies.

The concept map on life in the ocean (Martin et. al., 2000) as shown in Figure 3 by S1 depicts hierarchy using the linking words: 'consists of', 'have 2 groups', 'are either' and 'include'. Based on the traditional scoring model each level of hierarchy is scored for 5 points and there appears 6 levels in the above hierarchy and so gets 30 points. The Novakian criteria to assign score for hierarchy is based on graphical and not semantic criteria. Logically, in a well-formed hierarchy the relation must use a transitive, asymmetric, and a single linking word consistently. In S1's map the first relation takes part in part-whole relation and all the others in the hierarchy take part in class-subclass relation, though S1 uses different linking words. Therefore, Novakian rubric fails to make this subtle distinction and commits a logical fallacy. This is a serious anomaly, and therefore we should find an appropriate refinement in validating hierarchies in the maps.

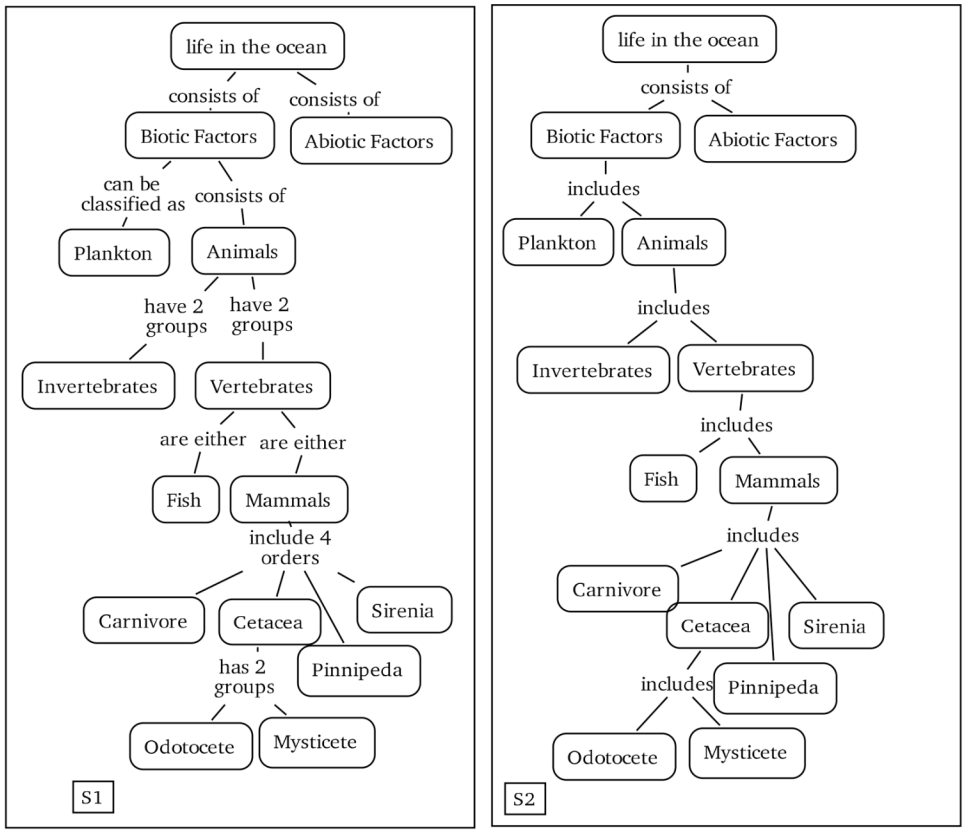


Figure 3. Concept maps on life in the ocean drawn by S1 and S2.

3 Discussion

Based on the examples that were considered above, we think, there is a need to attend to the problems, which can be handled properly by the concept mapping methodology, so that the restructuring will happen while extending the folk language to scientific language. Most of the problems can be resolved by focusing on the problem of choosing the right kind of linking words. Ambiguity in linking phrases and lack of rigor in concept mapping is already reported by other researchers (Costa et al., 2004). In the Artificial Intelligence (AI) community concept maps are considered as non-rigorous in methodology (Kremer, 1995; Sowa, 1984; Sowa, 2006), and the maps lack in Knowledge Representation (KR) formalisms (Cañas & Carvalho, 2004). This point of critique is cited in the works of Cañas, et. al. (2004) from IHMC to show that concept maps and AI (or KR) are not compatible.

Despite the fact that there is freedom in selecting linking words, and though it gives an unlimited expressive power, it gives rise to ambiguity in concept maps. Most often the linking words used, are borrowed from the natural language, and may lead to ambiguity. The purpose of concept maps to help in meaningful learning is not achieved when the resulting concept maps are ambiguous and lead to vague understanding. While acknowledging that students begin with a rich tapestry of folk language, when they begin to learn science they are required to weed out expressions. The requirement by the AI community to weed out ambiguity is somewhat related to this, since computing systems cannot handle implicit knowledge. Similarly, scientific language strives to be as explicit as possible. If we recall what happened in each of the great scientific revolutions, we will realize that so much effort was spent by the masters, such as Galileo, in conceptual cleansing. In fact it was argued that revolutionary changes took place due to change in conceptual schemes (see the case studies in Nagarjuna, 1994). Therefore, we think that during the process of learning science, we need to create an opportunity to restructure the concept maps drawn while learning in any domain so that the students reach as close to the expert's knowledge structure as possible.

If our line of thinking is valid, then the task is to identify an operational way of bringing modifications to the concept mapping methodology. Having already identified that the main problem is with respect to the linking words,

let us focus on what we can do here. Though we may think that there can be innumerable number of linking words, if we look closely into any expert domain in any science, we realize that the number of *kinds* of linking words is limited, and does not increase as the knowledge advances. Let us call the kinds of linking words as *relation types*. Take any large concept map of any domain, and take a measure of the number of relation types used to re-represent the knowledge. We hypothesize that the number reaches very quickly a constant figure for each domain of knowledge and does not increase any further. Our hypothesis has already some support from the preliminary evidences of Fisher's work. A biology network created by a team revealed 67 relations used to link about 2,300 concepts (Fisher, 1990, pg. 1003). Our ongoing research further substantiates our hypothesis, and we will report the results on another occasion. In a study conducted by us, a chapter from the Class VIII science textbook was re-represented as a concept map by carefully choosing accurate relation types. We found that the entire knowledge of the chapter needed only 6 relation types in a network of about 70 propositions (Kharatmal, 2006). If our argument that experts tend to use less number of relation types has any weight, then while using concept mapping technique in science education we should make a special effort to inculcate discipline in choosing the right kind of relation types. It may not be inappropriate to give a higher score for choosing the right kind of relation type while making the maps. If accurate use of relation type is a good index of expertize and restructuring of knowledge, every valid relation type should be given a higher score. We are not proposing a specific value for the score yet, and may be decided by experts in knowledge mensuration. Our purpose is to initiate a discussion.

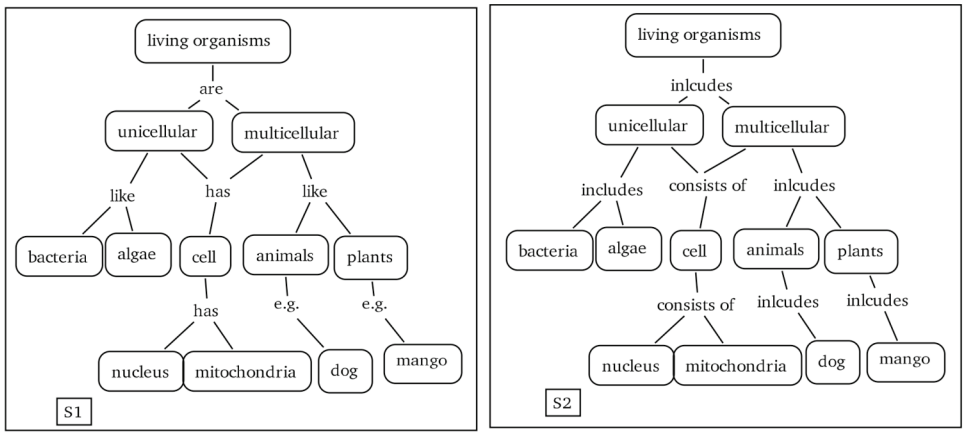


Figure 4. Concept maps on living organisms drawn by S1 and S2.

By taking care of appropriate relation types, the problem reported above on the hierarchy also gets resolved. Consider the maps drawn in Figure 4. By the traditional method the map drawn by S1 has three levels of hierarchy. However, the same map is re-represented by us as S2 using our proposed discipline. We see two distinctly valid hierarchies, one for the relation type 'consists of' which has two levels, and the other using the relation type 'includes' which has three levels. Clearly the former one is a hierarchy of part-whole relation, and the latter is of class-subclass relation. This rigor, we think, is necessary for science education, and reflects the restructuring that takes place while becoming an expert.

In this paper we have identified certain anomalies in the existing concept mapping and scoring methodology, particularly keeping in mind the use of concept mapping for science education. We have attempted to show that the traditional rubric is inefficient in capturing and comparing the knowledge restructuring during the transition from the novice to an expert. We have proposed that if concept mapping methodology is refined by attending to the problems and by following a few suggestions made in this paper, it can become a more effective tool in studying the structure and dynamics of knowledge.

4 References

Ausubel, D., Novak, J., and Hanesian, H. (1978). Educational Psychology: A Cognitive View. New York: Holt, Rinehart and Winston.

Arnaudin, M. A., Mintzes, J. J., Dunn, C. S., & Shafer, T. H. (1984). Concept mapping in college science teaching. Journal of College Science Teaching, 117—121.

Cañas, A. J., & Carvalho, M. (2004). Concept Maps and AI: an Unlikely Marriage? In *Proceedings of SBIE 2004: Simpósio Brasileiro de Informática Educativa*. Manaus, Brasil: SBC.

Carey, S. (1986). Conceptual change and science education. American Psychologist, 41(10), 1123--1130.

Costa, J. V., Rocha, F. E., & Favero, E. L. (2004). Linking phrases in concept maps: A study on the nature of inclusivity. In A. J. Canas, J. D. Novak, & F. M. Gonzalez (Eds.), Concept Maps: Theory, Methodology, Technology. Universidad Publica de Navarra, Pampalona, Spain.

Fisher, K. (1990). Semantic networking: The new kid on the block. Journal of Research in Science Teaching, 27(10), 1001--1018.

IHMC CmapTools (2004). The Website of CmapTools. http://cmap.ihmc.us.

Kharatmal, M. (2006). Concept map on cell structure and function. At IHMC Public Cmaps \ Meena (India) \ Cell Structure and Function \ Cell Structure and Function. http://skat.ihmc.us/servlet/SBReadResourceServlet?rid=1139090479160_113084903_8482&partName=htmltext

Kremer, R. (1995). The design of a concept mapping environment for knowledge acquisition and knowledge representation. Proceedings of the 9th International Knowledge Acquisition Workshop.

Kuhn, T. (1962) The Structure of Scientific Revolutions. USA: University of Chicago Press.

Markham, K. M., Mintzes, J. J. & Jones, M. G. (1994). The concept map as a research and evaluation tool: Further evidence of validity. Journal of Research in Science Teaching, 31(1), 91—101.

Martin B. L., Mintzes, J. J., & Clavijo, I. E. (2000). Restructuring knowledge in biology: Cognitive processes and metacognitive reflections. International Journal of Science Education, 22(3), 303-323.

Mintzes, J. J. (In Press). Knowledge restructuring in biology: Testing a punctuated model of conceptual change. International Journal of Science and Mathematics Education.

Mintzes, J. J., Wandersee, J., & Novak, J., (Eds.). (1998). Teaching Science for Understanding --- A Human Consctructivist View. USA: Academic Press.

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (1997). Meaningful Learning in Science: The Human Constructivist Perspective. In Gary D. Phye (Ed.), Handbook of Academic Learning: Construction of Knowledge (pp. 405-47). USA: Academic Press.

Nersessian, N. J. (1998). Conceptual change. In W. Bechtel, & G. Graham (Eds.), A Companion to Cognitive Science. Blackwell, Malden, MA. 155-166.

Nagarjuna, G. (working paper). From Folklore to Science. Paper presented at the Eighth International History, Philosophy, Sociology & Science Teaching Conference, Leeds, UK, July 15-18, 2005.

Nagarjuna, G. (1994). The Role of Inversion in the Genesis, Development and the Structure of Scientific Knowledge. Ph.D. Thesis, Department of Humanities and Social Sciences, Indian Institute of Technology, Kanpur, India. http://cogprints.org/4340/

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Sowa, J. (2006). Concept mapping. Talk presented at the AERA Conference, San Francisco. http://www.jfsowa.com/talks/cmapping.pdf

Sowa, J. (1984). Conceptual Structures: Information Processing in Mind and Machine. USA: Addison-Wesley Publishing Company.

Thagard, P. (1992). Conceptual Revolutions. USA: Princeton University Press.

Thompson, T. L., & Mintzes, J. J. (2002). Cognitive structure and the affective domain: On knowledge and feeling in biology. International Journal of Science Education, 24(6), 645-600.

Vosniadou, S. & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. International Journal of Science Education, 20(10), 1213-1230.

Wallace, J. D., & Mintzes, J. J. (1990). The concept map as a research tool: Exploring conceptual change in biology. Journal of Research in Science Teaching, 27(10), 1033--1052.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

A CONCEPT MAPPING SCORING ALGORITHM BASED ON PROPOSITION CHAINS

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Abstract. Concept maps are widely used in education and have a significant impact on teaching and learning, but it's really a challenge for teachers and researchers to assess concept maps both efficiently and effectively. Computer-based Concept Mapping Systems (CCMS) have been developed to assess concept maps automatically. However, current scoring methods applied in the CCMS mainly focus on the match of concept nodes, relation links or each separate proposition, paying little attention to the relationship between propositions. In this paper we propose a novel scoring algorithm based on Proposition Chains. Considering concept maps as directed graphs, we define a Proposition Chain as a linked list consisted of all the propositions in one of the longest paths in the graph, thus it can show the relationship among a group of propositions. We aim to solve some problems existing in previous scoring methods and we believe that the proposed scoring algorithm can be easily applied in the CCMS because of its simple storage structure and explicit scoring procedure.

1 Introduction

Based on the learning psychology of David Ausubel, Prof. Joseph D. Novak at Cornell University presented concept map as an instructional technique in the 1980's. According to Novak (1982), concept maps are tools for organizing and representing knowledge. One of its original uses in education is to assess what a learner already knows (Coffey et. al., 2003). Over the last 20 years, concept maps have been widely used in education.

Since concept map is considered as a great teaching and learning tool, many educators and researchers put emphasis on assessing concept maps. When using paper and pencil, people spent lots of time and energy drawing and assessing concept maps. To cope with this problem, computer-based concept mapping systems (CCMS) have been developed. It should be noted that the scoring methods mentioned in this paper refer to what could be applied in CCMS. Since a computer can not understand semantics of concept maps all by itself, the usual solution is to use a reference map. The similarity value is decided through the comparison of a concept map and a relevant reference map.

A considerable amount of researches have been done during the last few decades and various scoring methods have been proposed (Lomask et al., 1992; McClure & Bell, 1990; Novak & Gowin, 1984; Acton et al., 1994; Goldsmith, Johnson, & Acton, 1991). Actually each scoring method or algorithm has its advantages and limitations. Many researchers also made changes or improvements to these existing scoring methods for their own purposes (Markham, K., Mintzes, J. & Jones, G., 1994; Chen et al., 2003; Chang et al., 2005; Agrawal & Srikant, 1996). Generally speaking, previous methods mainly take concepts nodes, relation links or each separate proposition into consideration. However, they may not take proposition as a whole or lack consideration of hierarchical levels (Chen et. al., 2003); or there may be no explicit instructions on how to score it (Novak & Gowin, 1984), etc. On the basis of previous methods, we present a new algorithm based on Proposition Chains. We aim to solve some problems existing in previous scoring methods and we believe it can be easily applied in the CCMS. This algorithm takes propositions as basic scoring items, and its purpose is to represent and assess the semantic meanings between propositions through the mode of Proposition Chain.

2 Basic Terminologies and Assumptions

We will provide in this section basic terminologies and assumptions which are necessary for the understanding of subsequent algorithm. Concept maps consist of concept nodes and relation links between the concept nodes. According to Novak and Gowin(1984), concept maps are intended to represent meaningful relationships in the form of propositions, which are defined as two concepts connected by a labeled arrow indicating the relationship between the concepts in a semantic unit. If $C= \{C_1, C_2, \ldots, C_m\}$ represents the sets of concept nodes, and $R= \{R_1, R_2, \ldots, R_n\}$ represents the sets of relation links, we define a concept map as a directed graph $CM= (C, R)$. If $c_i, c_j \in C$, $r_{ij} \in R$, then $P= (c_i, r_{ij}, c_j)$ represents a proposition in this concept map, and r_{ij} includes both the relationship and direction of c_i and c_j.

The assessment discussed in this paper includes reference maps and to-be-assessed maps. A reference map (R-map) is drawn by teachers or domain experts, while a to-be-assessed map (A-map) is usually constructed by students. For a specific concept map task, there is only one R-map with several A-maps. We compare each A-map to the R-map, and then we can get the similarity value of each A-map. In a specific task, there's always a main topic concept node, which we ask the teachers or experts to mark after they finish the R-map. This main topic concept node is defined as a root node in our comparison procedure.

2.1 Accuracy of Proposition

Ruiz-Primo and Shavelson (1999) state that they favor scoring criteria that focus more on the adequacy of the propositions over those that focus simply on counting the number of map components (e.g. nodes and links). Accuracy of proposition in this paper means the correctness of each separate proposition of the A-maps compared with the R-map. According to the method proposed by McClure and Bell (1990) and the assessment using "weighted concept map" by Chang et al. (2005) , we define the accuracy of propositions at three levels: correct, partially correct and incorrect. Let CM = (C, R) be a R-map and $CM^S = (C^s, R^s)$ be a A-map. If $c_i, c_j \in C$ and $r_{ij} \in R$, then $P_{r_{ij}} = (c_i, r_{ij}, c_j)$ represents a proposition in CM.

Situation 1: If (1) $c_i \notin C^s$, or (2) $c_j \notin C^s$, or (3) $c_i, c_j \in C^s$, but there's no relation link between them, namely $P^s_{r_{ij}} = (c_i, r'_{ij}, c_j)$ or $P^s_{r_{ij}} = (c_j, r'_{ij}, c_i)$ does not exist in the A-map, we deem that the mapper doesn't grasp the relationship between concept nodes c_i and c_j, so that the proposition is incorrect.

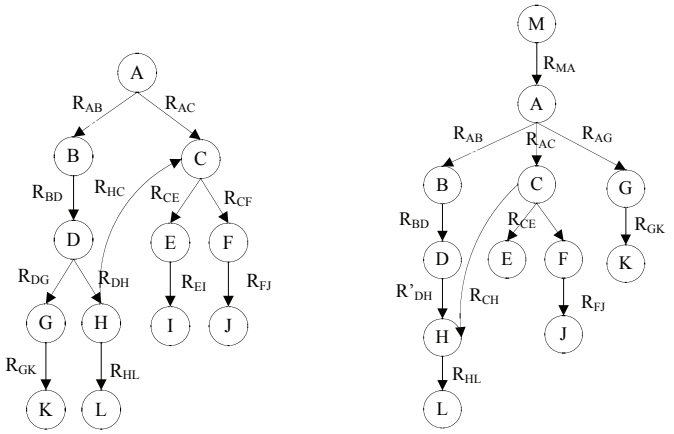
Situation 2: If $c_i, c_j \in C^s$ and $r'_{ij} \in R^s$, then $P^s_{r_{ij}} = (c_i, r'_{ij}, c_j)$ or $P^s_{r_{ij}} = (c_j, r'_{ij}, c_i)$ represents a proposition in CM^S. The following procedure shows how to judge the accuracy of propositions in the basic scoring algorithm based on Proposition Chains. Details in the extended scoring algorithm are discussed in later section.

1. If there is a proposition $P^s_{r_{ij}} = (c_i, r'_{ij}, c_j)$ in the A-map, then: (1) If $r'_{ij} = r_{ij}$, $P^s_{r_{ij}}$ is correct; (2) If $r'_{ij} = \Phi$, $P^s_{r_{ij}}$ is partially correct (We use Φ as the symbol of lacking label of the relation link. similarly hereinafter.); (3) If $r'_{ij} \neq r_{ij}$ (not including $r'_{ij} = \Phi$), $P^s_{r_{ij}}$ is incorrect.
2. If there is a proposition $P^s_{r_{ij}} = (c_j, r'_{ij}, c_i)$ in the A-map, then: (1) If $r'_{ij} = \Phi$, $P^s_{r_{ij}}$ is partially correct; (2) If $r'_{ij} \neq \Phi$, $P^s_{r_{ij}}$ is incorrect.

2.2 Proposition Chains

According to Novak (1984), the scoring method contains four components, including propositions, hierarchies, cross-links and examples. However, Novak also claims that it may appear disturbing to see that the same sets of concepts can be represented in two or more valid hierarchies. When the concept map is organized in a network structure or the hierarchy structure isn't obvious, we can hardly distinguish the hierarchies of a map or decide whether the relation links are cross-links or not.

Considering concept map as a directed graph, we define a Proposition Chain as a linked list consisting of all the propositions in one of the longest paths in the graph, thus it can show the relationships among a group of propositions. Proposition Chains integrate concept nodes, relation links, hierarchies and semantics altogether and imply the hierarchy structure from generalization to specification. Each Proposition Chain can be translated into a sentence with continuous semantic understanding between concepts. A concept map can be taken apart into several Proposition Chains. The R-map shown in **Figure 1** includes six Proposition Chains in it. For example, it forms a Proposition Chain from concept nodes A to K, so $PC_1 = \{(A, R_{AB}, B), (B, R_{BD}, D), (D, R_{DG}, G), (G, e.g., K)\}$ is a Proposition Chain with four propositions.



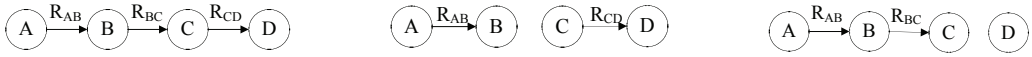
(a) reference maps (b) to-be-assessed map

Figure 1. An example of a R-map and a A-map

2.3 Discontinuity of a Proposition Chain

Compared with a Proposition Chain in the R-map, discontinuity of this Proposition Chain may occur in an A-map. We define the discontinuity of a Proposition Chain in a A-map as that there is no relation link between two certain concept nodes or the accuracy of certain propositions is incorrect compared to the relevant Proposition Chain in the R-map. As shown in **Figure 2**, the reference Proposition Chain (a) embodies three propositions. As there's no relation link between concept nodes B and C in A-map (b), we define the Proposition Chain discontinued once. The discontinuity of a Proposition Chain signifies the interruption of semantics, thus points should be subtracted.

It is noted that there's an exception. As in **Figure 2**, the A-map (b) and (c) each form only two propositions comparing to R-map (a). When the discontinuity occurs at the end of the Proposition Chain such as A-map (c), the first two propositions still seem to express a continuous meaning. Therefore, the situation with discontinuity at the start or the end of a Proposition Chain doesn't count.



(a) a Proposition Chain (reference maps) (b) discontinuity (to-be-assessed map) (c) non-discontinuity (to-be-assessed map)

Figure 2. Diagram of discontinuity of a Proposition Chain

2.4 Leap Relationship

Only in the extended algorithm we take leap relationship into consideration, because it may refer to the semantic match of concepts. A proposition appears in an A-map may not exist in an R-map. However, if the concept nodes c_i and c_j, which form a proposition $P_{r_{ij}} = (c_i, r_{ij}, c_j)$ in the A-map, also exist in the R-map but connect indirectly, then we call the relation link r_{ij} in the A-map as a leap relationship. We define $F_{r_{ij}}$ as leap value, and it shows the hierarchy level between the two concept nodes in the R-map. We should mark all the concept nodes in a Proposition Chain. The start node of a Proposition Chain is marked as level 1, and other nodes is marked as their own hierarchy levels H_{c_i} by increasing numbers. Thus, the leap value $F_{r_{ij}}$ between concept nodes c_i and c_j is computed as follows:

$$F_{r_{ij}} = H_{c_j} - H_{c_i} .$$

We still take reference Proposition Chain (a) in **Figure 2** as an example. **Figure 3** shows a to-be-assessed Proposition Chain and concept nodes B and D connect directly without the concept node C existing in the reference Proposition Chain. Then relation link R_{BD} is a leap relationship. We mark concept node B as level 2, and D as level 4 in the reference Proposition Chain. According to the formula described above, the leap value $F_{R_{BD}}$ =4-2=2.

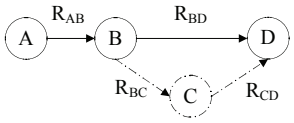


Figure 3. Diagram of a leap relationship in a A-map

3 Scoring algorithm based on Proposition Chains

A concept map can be constructed with created linking phrases (C) or with selected linking phrases (S). Yue Yin et al. (2005) conclude that the C technique is better than the S technique in capturing students' partial knowledge, even S technique can be scored more efficiently than C. Since a computer can not understand the semantics of concept maps all by itself, we divide the scoring algorithm into two categories: the basic one and the extended one. When constructing a map with selected phrases, we choose basic algorithm. When constructing a map with created linking phrases, we should consider the factors mentioned in the extended algorithm. As Debbie (2004) concludes, comparisons between an R-map and A-maps are a relatively new area of research and require an algorithm and computer program to quantify the maps. The scoring algorithm based on Proposition Chains will be described in detail as the following.

3.1 Basic Scoring Algorithm Based on Proposition Chain

Step1, traverse the R-map, collect the sets of reference Proposition Chain, and calculate the total score of R-map. This step is only taken in the R-map. We define the root node marked by teachers or experts as search start. Using Deep-First-Search algorithm, we start searching from the root node to other nodes along the outgoing arc. When visiting a visited node or the node's outgoing arc is minimized (usually zero), the search stops and the longest proposition sets formed during the search is called a Proposition Chain. In the case that the search stops when reaching a visited node, this node becomes the last node of this proposition chain. We collect all the Proposition Chains existing in an R-map by back-tracking algorithm, and form a set of Proposition Chain $\{ PC_n \}$. During the search process, we should record some important information and calculate some necessary data.

- **Sets of Proposition Chain $\{ PC_n \}$.** Concept nodes and relation links are important elements in the Proposition Chains when matching. We should calculate the number of propositions $N(PC_n)$ in every Proposition Chain.
- **Hierarchy Level of Each Concept Node H_{c_i}.** The hierarchy level of each concept node in every Proposition Chain should be marked, as the same concept node may appear in different Proposition Chains at a different hierarchy level.
- **Score of R-map S(PC_n).** Assume each proposition in a R-map values 1 point, then the total score of a R-map is computed as follows:

$$S(PC_n) = \sum_{n=1,2,...,N} N(PC_n).$$

Step2, traverse the A-map, collect the sets of to-be-assessed propositions, compare each proposition with the R-map, and calculate the total score of the A-map. This step is only taken in the A-map. We need to compare each proposition in the A-map with the sets of Proposition Chains in the R-map. During the match process, the accuracy of propositions and discontinuity of a Proposition Chain should be taken into consideration.

- **Sets of To-be-assessed Propositions $\{ P^s_{r_{ij}} \}$.** Traverse the A-map, and store all propositions in detail (including both concept nodes and relation links), then forms the sets of propositions $\{ P^s_{r_{ij}} \}$.
- **Match Score of Proposition S(PC^s_n).** Compare a proposition in a A-map with all the Proposition Chains in the R-map, and make a mark of the Proposition Chain in R-map when they match. Assuming that the accuracy of proposition value is $A_{P^s_{r_{ij}}}$, we define $A_{P^s_{r_{ij}}}$ as 1 point when proposition is correct, 0.5 point when it's partially

correct, and 0 point when it's incorrect value $A_{P^s_{r_{ij}}}$=0. According to the accuracy of each proposition, we can add up the scores of all matches, then the total score of a Proposition Chain is:

$$S(PC^s_n) = \sum_{P^s_{r_{ij}} \in \{PC^s_n\}} A_{P^s_{r_{ij}}} .$$

- **Score of Discontinuity in a Proposition Chain S($D_{PC^s_n}$).** According to the sets of propositions $\{ P^s_{r_{ij}} \}$ in an A-map, we can count the discontinuity numbers of a Proposition Chain compared with an R-map. Assume discontinuity in a Proposition Chain is computed as follows:

$$S(D_{PC^s_n}) = \frac{N(D_{PC^s_n})}{N(PC_n)} .$$

Step3, calculate the similarity value with comparison of R-map and A-map. Bring the scores of the above two steps into formula, and the similarity value is computed as follows:

$$\alpha = \frac{S(PC^s_n) - S(D_{PC^s_n})}{S(PC_n)} .$$

3.2 Extended scoring algorithm based on Proposition Chain

The extended algorithm is presented to score concept maps constructed with created phrases. The difference between the basic and extended algorithm is how to judge the accuracy of a proposition and deal with the additional propositions. Moreover, the emphasis is placed on the semantic match.

3.2.1 Accuracy of propositions

The judgment of the accuracy of proposition is just the same as what we presented above, except for a minor change in situation 2. If there is a proposition $P^s_{r_{ij}} = (c_j, r'_{ij}, c_i)$ in the A-map, then: (1) If $r'_{ij} = r_{ji}$, $P^s_{r_{ij}}$ is considered to be correct because r_{ji} has the opposite semantic meaning; (2) If $r'_{ij} = \Phi$, $P^s_{r_{ij}}$ is partially correct; (3) If $r'_{ij} \neq r_{ij}$ (not including $r'_{ij} = r_{ji}$), $P^s_{r_{ij}}$ is incorrect.

3.2.2 Sets of additional propositions

We record the propositions in an A-map but not in the R-map, and they form the sets of additional propositions $\{ P^s_{add} \}$. The leap relationship is among the additional propositions. If the leap relationship is correct, we should add some reasonable points to the total score, which we call the correct score of leap relationships S($L^s_{r_{ij}}$). Whether the leap relationship is correct or not depends on the types of the relation links and the transitivity of the link words. Based on the previous research, one may classify the type of the knowledge into the following items: (1) classification relation, (2) successive relation, (3) belonging relation, (4) causative relation, and (5) composition relation (SHEN Rui-min et. al., 2002). It can also be categorized into: (1) belonging relation, (2) characteristic relation, (3) causative relation, (4) functional relation, (5) explanation relation, (6) definition relation, (7) example relation, and (8) type relation, etc (Novak & Gowin; Holley, Dansereau, McDonald, Garland & Collins). If the type of relation links is appropriate, then we can put them in certain sequences to transfer the semantic meaning of propositions. We can not describe the detailed information here as it's a complex problem to explain when and how it can transfer the semantic meanings.

In **Figure 4**, for example, the R-map (a) shows a Proposition Chain with two propositions including (living thing, include, animals) and (animals, include, vertebrates)}. If only one proposition (living thing, include, vertebrates) appears in the A-maps, we consider it as partially correct, for relation link word "include" can somewhat transfer the semantics.

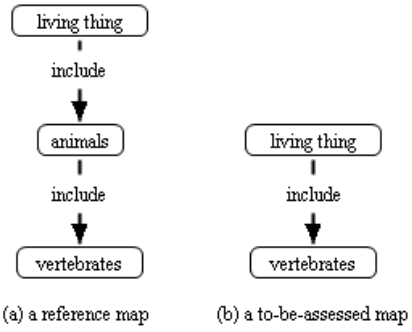


Figure 4. An example of Leap Relationship

To show the influence on Proposition Chains, we define the correct leap relationship index as $\frac{1}{L_{r_{ij}}}$. In terms of student's understanding, the more intervals there are between hierarchies, the more obscure cognitive recognition it reflects, and the fewer score should be given. So the score of corrected leap relationship should be calculated as follows:

$$S(L^{s}_{r_{ij}}) = \sum \frac{1}{L_{r_{ij}}}.$$

Except for the leap relationships, other additional propositions existing should be assessed by human judgment. We record them as feedback information to students but do not deal with them.

3.2.3 Similarity value of the A-map

The method is similar to that in the basic scoring algorithm, but it requires consideration of considering two more factors mentioned in the sections above. Bring all the scores into the formula as follows:

$$\alpha = \frac{S(PC^{s}_{n}) - S(D_{PC^{s}_{n}}) + S(L^{s}_{r_{ij}})}{S(PC_{n})}.$$

4 Example analysis

Since constructing a map with selected phrases can be more easily assessed, the following example is only for the purpose of illustrating the procedure of extended algorithm. An example of concept map is shown in **Figure 1**. Note that: (1) the identical symbols in the R-map and the A-map indicate complete consistency. (2) The relation R'_{DH} in the A-map between nodes D and H is different from that in the R-map. (3) There's no relation link label between concept nodes C and F in the A-map. (4) Both the direction and semantic of relation link label between concept nodes C and F in the A-map is opposite to that in the R-map. Applying the scoring algorithm based on Proposition Chains to the example, we can get the following score.

Step 1, traverses the R-map, collects the sets of Proposition Chains, and calculate the number of propositions in each Proposition Chain as follows:

PC_1={(A, R_{AB}, B), (B, R_{BD}, D), (D, R_{DG}, G), (G, R_{GK}, K)},
PC_2={(A, R_{AB}, B), (B, R_{BD}, D), (D, R_{DH}, H), (H, R_{HL}, L) },
PC_3={(A, R_{AB}, B), (B, R_{BD}, D), (D, R_{DH}, H), (H, R_{HC}, C) , (C, R_{CE}, E), (E, R_{Ei}, I)},
PC_4={(A, R_{AB}, B), (B, R_{BD}, D), (D, R_{DH}, H), (H, R_{HC}, C) , (C, R_{CF}, F), (F, R_{FJ}, J)},
PC_5={(A, R_{AC}, C), (C, R_{CE}, E) , (E, R_{Ei}, I)},
PC_6={(A, R_{AC}, C), (C, R_{CF}, F), (F, R_{FJ}, J)}.
$N(PC_n)=N(PC_1)+N(PC_2)+N(PC_3)+N(PC_4)+N(PC_5)+N(PC_6)=4+4+6+6+3+3=23$.

Step2, traverse the A-map, and make marks in the Proposition Chains as above. The mark is described as: (1) the straight underline represents correct propositions and scores 1 point, (2) the dashed underline represents partially

correct propositions and scores 0.5 point, and (3) the unmarked proposition is incorrect or missing and scores 0 point. Then the match score and discontinuity scores of each proposition is as follows:

$$S(PC_1^s)=3,\ S(PC_2^s)=3,\ S(PC_3^s)=4,\ S(PC_4^s)=4.5,\ S(PC_5^s)=2,\ S(PC_6^s)=2.5.$$

$$N(D_{PC_1^s})=N(D_{PC_2^s})=N(D_{PC_3^s})=N(D_{PC_4^s})=1,\ N(D_{PC_5^s})=N(D_{PC_6^s})=0.$$

$$S(D_{PC_1^s})=S(D_{PC_2^s})=1/4\ \square\ S(D_{PC_3^s})=S(D_{PC_4^s})=1/6\ \square\ S(D_{PC_5^s})=S(D_{PC_6^s})=0$$

The set of additional propositions P_{add}^s consist of (M, R_{MA}, A) and (A, R_{AG}, G). R_{AG} is shown to be a leap relationship, and the hierarchy level value in Proposition Chain PC_1 is $L_{r_{ij}} = H_{c_j} - H_{c_i} = 4-1=3$. Assuming that R_{AG} indicates reasonable semantics, the score of correct leap relationship $S(F_{r_{ij}}^s) = 1/3$. As R_{MA} appears to be an additional relation link, we just record it for a feedback. The proposition (E, R_{EI}, I) is missing, and we record it for a feedback as well. Then, we can get the similarity value of this A-map as follows:

$$\alpha = \frac{(3+3+4+4.5+2+2.5)-(1/4+1/4+1/6+1/6)+1/3}{23} = 80.43\% .$$

5 Discussion and Future Work

The most important function of concept map is to facilitate the learners' thinking, comprehension and recollection through the process of concept mapping. The educators score the concept map in order to do quantitive analysis, or compare the students' pre and post learning effects. Some important information will absolutely be lost if only considering quantitive assessment. Therefore, we should explain the score scientifically concluded by the scoring algorithm of Proposition Chains. It is important to point out that the similarity value only shows the exactitude rate of a A-map compared with a R-map.

The scoring methods for concept mapping are established step by step with modification and will never set a standard criterion. According to Novak and Gowin (1984), any scoring key, as well as the numerical scores employed to score concept maps, is somewhat arbitrary and subjective. He encourages educators to experiment with different values. Few of the published scoring methods can be applied to the CCMS, especially when constructing a map with created phrases. We attempt to integrate useful parts of previous scoring methods into the proposed algorithm, and try to solve the problems existing in them. Theoretically, the advantages of applying the scoring algorithm based on Proposition Chains to the CCMS are: (1) clear scoring steps, (2) standardized scoring rules, (3) simple storage structure. In addition, Chinese concept map software "Easy Thinking-Cognitive Assistant" is under development by Institute of Knowledge Science & Engineer in BNU, and we will choose this new scoring algorithm as its basic scoring rule.

We have just started our research in automated assessment of concept maps, and both theoretical and practical problems that are waiting forward need to be tackled at the moment. Just like the research done by Scott et al. (2004) in an online concept mapping tool "C-TOOLS", the percentage of automated-assessed propositions is still low with the help of software "Robograder™ and WordNet®". The CCMS need a huge word database as the support of semantic matches as well. At the same time, network supported collaborative concept mapping is popularized so fast that it becomes an important future research to design a criterion to score the work of individuals or groups. Since we haven't applied the proposed algorithm to real-world practice, its reliability and validity still need further evidence. Considerable more work needs to be done in this area.

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References

Agrawal, R. & Srikant, R. (1996). Mining Sequence Patterns: Generalizations and Performance Improvements. In Proceedings of the 5th Int'l Conference on Extending Database Technology (EDBT), 3-17.

Chang, K.-E., Sung, Y.-T., Chang, R.-B., & Lin, S.-C. (2005). A New Assessment for Computer-based Concept Mapping[J]. Educational Technology & Society, 8 (3), 138-148.

Chiu, C. H., Zhuang, Q. H., & Lin, J. L., (2003). Scoring concepts maps based on map structure and mapping process. Presented in 2003 International Conference on Computer Assisted Learning (ICCAI2003) (pp.160), Taipei, Taiwan, April 24-26, 2003. *(in Chinese)*

Chen Tzung-Shi, Li Hsin-Yi & Huang Shih-Ting. (2003). An Analysis Strategy of Structures of Computerized Concept Maps Applied on Mobile Learning for Elementary Education. Journal of Chang Jung Christian University, Special Issue for the University˙s 10th Anniversary, pp. 41-63, November 2003. *(in Chinese)*

Coffey, J. W., Carnot, M. J., Feltovich, P. J., Feltovich, J., Hoffman, R. R., Cañas, A. J., & Novak, J. D. (2003). A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support (Technical Report submitted to the US Navy Chief of Naval Education and Training)[R]. Pensacola, FL: Institute for Human and Machine Cognition, 2003: 7.

Debbie Denise Reese. (2004). Assessment and Concept Map Structure: The Interaction Between Subscores and Well-Formed Mental Models[C]. Paper presented at the annual meeting of the American Educational Research Association (AERA), San Diego, CA, April.

Goldsmith, T. E., Johnson, P. J. & Acton, W. H. (1991). Assessing structural knowledge[J]. Journal of educational psychology, 83(1), 88-96.

John R. McClure, Brian Sonak, Hoi K. Suen. (1999). Concept Map Assessment of Classroom Learning: Reliability, Validity, and Logistical Practicality[J]. Journal of Research in Science Teaching, Vol. 36, No. 4, 475–492.

Lomask, M., Baron, J. B., Greig, J., & Harrison, C. (1992). ConnMap: Connecticut's use of concept mapping to assess the structure of students' knowledge of science[C]. Paper presented at the annual meeting of the National Association of Research in Science Teaching, Cambridge, MA.

Markham,K., Mintzes, J. & Jones, G. (1994). The Concept Map as a Research and Evaluation Tool: Further Evidence of Validity[J]. Journal of Research in Science Teaching, 31(1): 91-101.

Novak, J. D., & Cañas, A. J. (2006). *The Theory Underlying Concept Maps and How to Construct Them* (Technical Report No. IHMC CmapTools 2006-01). Pensacola, FL: Florida Institute for Human and Machine Cognition. Available online at: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm.

Novak, J. D. & Gowin, D. B. Learning how to learn [M]. New York: Cambridge University Press, 1984: 36-37; 15; 97-107; 16-17; 105.

Maria Araceli Ruiz-Primo & Richard J. Shavelson. (1996). Problem and Issues in the Use of Concept Maps in Science Assessment[J]. Journal of Research in Science Teaching, 1996, 33(6):569-600.

Maria Araceli Ruiz-Primo, Richard J. Shavelson, & Susan Elise Schultz. (1997). On The Validity Of Concept Map-Base Assessment Interpretations: An Experiment Testing The Assumption Of Hierarchical Concept Maps In Science(CSE Technical Report 455)[R], National Center for Research on Evaluation, Standards, and Student Testing (CRESST), 1997: 3-5.

Scott H. Harrison, Joshua L. Wallace, Diane Ebert-May, & Douglas B. Luckie. (2004). C-TOOLS Automated Grading for Online Concept Maps Works Well With a Little Help From "WORDNET"[C]. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

SHEN Rui-min, TANG Yi-yang, HAN Peng, & YANG Fan.(2002) Intelligent Content Modifier Based on Concept Map Theory [J]. Journal of Shanghai Jiaotong University. Vol.36, No. 5, 698-701. *(in Chinese)*

Yue Yin, Jim Vanides, Maria Araceli Ruiz-Primo, Carlos C. Ayala, & Richard J. Shavelson (2004). Comparison of two concept-mapping techniques: Implications for scoring, interpretation, and use[J]. Journal of Research in Science Teaching, Vol. 42, No. 2, 166-184.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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ACCOMODATING INDIVIDUAL DIFFERENCES IN GROUP FORMATION FOR COLLABORATIVE CONCEPT MAPPING

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Abstract. In this paper we investigate the influence of individual differences in group formation for collaborative concept mapping tasks. The presented pilot study involved 21 students who constructed individual and group concept maps on the central concept "Computer Storage Units". Students were intentionally placed into groups based on their learning-style type; the Honey and Mumford style categorization and the visual/verbal dimension of Felder-Silverman model was used. Various combinations of groupings in terms of learning-style type and level of knowledge, were resulted. Data analysis focused on the influence of learning styles on learning effectiveness in terms of the level of individual learning, the level of collaborative learning and the level of interaction between individual and group. Results provided evidence about efficient grouping approaches, such as group formation based on (a) a mixture of Honey and Mumford learning styles including cases with an average preference on the four styles or a strong preference on particular styles, (b) a mixture of visual levels referring to the visual/verbal dimension, and (c) high or a mixture of knowledge levels. Moreover, evidence about the influence of both the visual/verbal dimension and knowledge level in group-interaction dynamics, was also provided.

1 Introduction

Concept mapping (CM) is one of the most useful cognitive strategies, with a strong theoretical and research background, which stimulates learners to articulate and synthesize their actual states of knowledge during the learning process (Jonassen, 1992). One of the most promising applications of concept mapping is its integration into collaborative learning activities, as research showed that with collaborative effort students could elaborate, refine, and improve their own knowledge structures. Stoyanova & Kommers (2002) investigated the learning effectiveness of CM for computer-supported collaborative problem-solving. They showed that shared cognition, when all members of a group collaboratively construct a map, is more effective than moderated and distributed collaboration.

Computers as well as Information and Communication Technology (ICT) has been used to support collaborative CM since the mid-1990s (Cañas et al., 2001). Nowadays, there is a trend towards the development of web-based tools with collaborative facilities and current focus of research is on the development of web-based CM environments with synchronous and asynchronous communicative facilities (Cañas et al., 2001; Luckie et al., 2004). To this direction, the development of web-based CM environments needs to initially investigate the various aspects of collaboration. An important issue to consider is group formation, that is the grouping of learners with respect to their individual differences, aiming to promote effective collaboration in the context of a concept mapping activity.

In this paper we present a pilot study conducted to investigate group formation for collaborative concept mapping activities, accommodating learners' individual differences in terms of their learning styles and knowledge level. The aim is to provide evidence about how to form efficient groups when the learning style and the knowledge level of the students are known. This study is the first step towards the development of an automatic group formation tool, which will be incorporated in the web-enabled CM learning environment COMPASS (COncept MaP ASSessment & learning environment) (http://hermes.di.uoa.gr/compass) (Gouli et al., 2004). COMPASS serves assessment and learning by employing a variety of concept mapping activities, applying a scheme for the qualitative and quantitative estimation of learner's knowledge and providing different informative, tutoring and reflective feedback components, tailored to learners' individual characteristics and needs.

2 Group Formation of Students

Student learning differs as students differ in their general skills, aptitudes, and preferences for processing information (Jonassen & Grabowski, 1993). In particular, learning styles are related to mental abilities because most of us prefer to use the mental abilities and cognitive controls and styles with which we are more skilled and familiar. Moreover, the nature of the thinking and learning processes varies with the task. In our case, the task that learners need to collaboratively undertake is the construction of a concept map. We decided to investigate the influence of

two learning styles categorizations in students' learning and collaboration: (a) the Honey and Mumford (1992) style categorization as it concentrates on how people learn and deals with the social dimension of learning, as well as (b) the visual/verbal dimension of Felder-Silverman (1988) model mainly because of the nature of the concept mapping task – learners need to graphically organize and relate concepts in a map.

Honey and Mumford (1992, p. 1) define a learning style as being "a description of the attitudes and behaviour, which determine an individual's preferred way of learning". Based on Kolb's learning cycle, Honey and Mumford built a typology of Learning Styles, identifying individual learning preferences for each stage of the learning cycle. The four learning styles are described as those of Activists (gregarious, seek challenge and immediate experience), Reflectors (gather data, ponder and analyse, delay reaching conclusions, listen before speaking), Theorists (think things through in logical steps, assimilate disparate facts into coherent theories, rationally objective) and Pragmatists (seek and try out new ideas, practical, enjoy problem solving and decision-making quickly). Students, during the study, responded to the 80-item Honey and Mumford Learning Styles Questionnaire (LSQ) (1992), which determine preferences with regard to learning. Students were characterised based on their strong preferences (if any) on the different styles and not based on their max value on one of the styles. Thus, a student may be categorized as Activist, Reflector, Theorist, Pragmatist, or combinations such as Activist-Reflector or average on the four styles. This way, we aim to avoid the "danger of labelling people as 'Theorists' or 'Pragmatists', when most people exhibit more than one strong preference (Coffield et al., 2004). The Felder-Silverman model (1988) has four independent dimensions: the sensing/intuitive, the active/reflective, the visual/verbal and the sequential/global dimension. Particularly, the visual/verbal dimension describes the extent to which an individual favours information conveyed as images or as text. The Index of Learning Styles (ILS) questionnaire (1999) (44 items) was used to assess the style of each participant according to the visual/verbal dimension of the Felder-Silverman model. In particular, we acknowledge levels of the visual/verbal dimension, i.e. a student may be characterized as high/average/low visualiser/verbaliser.

Rational for Groupings. To understand the influences of learning styles, students were intentionally placed into groups based on their learning-style type. The knowledge level of the students was not taken into account in the group formation process. However, various combinations of learning-style type and level of knowledge (students' knowledge level was evaluated in the course of the study through their individual maps) groupings were constructed. Another aspect of our study centered on the dynamics of the interactions between students within the groups. It was assumed that the influence of a group member on the final product of the group depends on the learning style type and the knowledge level of the individual.

Groups	Students	H&M	Visual/ Verbal	Groups	Students	H&M	Visual/ Verbal
Group A	Student1	Average Values	Low Visualiser	Group E	Student1	Reflector	Low Visualiser
	Student2	Average Values	Low Visualiser		Student2	Reflector	High Visualiser
	Student3	Average Values	Low Visualiser		Student3	Reflector	Low Verbaliser
Group B	Student1	Average Values	Medium Visualiser	Group F	Student1	Activist	High Visualiser
	Student2	Average Values	Low Visualiser		Student2	Reflector	High Visualiser
	Student3	Average Values	High Visualiser		Student3	Theorist	Medium Visualiser
Group C	Student1	Activist	Medium Visualiser	Group G	Student1	Activist-Pragmatist	High Visualiser
	Student2	Reflector	Medium Visualiser		Student2	Reflector-Theorist	Medium Visualiser
	Student3	Activist	Medium Visualiser		Student3	Activist	Medium Visualiser
Group D	Student1	Max Values	Low Verbaliser				
	Student2	Max Values	High Visualiser				
	Student3	Min Values	Medium Visualiser				

Table 1: Groupings of students.

Groupings of Students. The following groupings (Table 1) were intentionally made to create a combination of similar and dissimilar learning styles following Honey and Mumford's categorization (H&M) and/or the visual/verbal dimension of the Felder-Silverman model (F&S). Group A was comprised of students with average preferences on the H&M styles, and low visualisers. Group B was comprised of students with average preferences on the H&M styles and with varying visual levels. The students of Group C had varying H&M learning styles (2

Activists and 1 Reflectors) with an average visual level. Group D was comprised of students with a range of styles (2 having max values and 1 min values at the H&M learning style categories), with varying visual/verbal styles (1 high and 1 medium visualiser, 1 low verbaliser). Group E was comprised of Reflectors, with varying visual/verbal styles (1 high and 1 low Visualiser, 1 low Verbaliser). The students of Group F had varying H&M learning styles (1 Activist, 1 Reflector, 1 Theorist), with high visual levels (2 high and 1 medium Visualiser). The students of Group G had varying H&M styles (1 Activist-Pragmatist, 1 Reflector-Theorist, 1 Activist), with medium/high visual levels.

3 Design of the Study

Research Questions. There were two research questions guiding the study. The first was "What are the effects of learning style on students' group concept maps". The second research question was "How the learning style and knowledge of an individual influence the group concept maps and the group-interaction dynamics in terms of how s/he influences the final product?".

Method. Twenty-one 4th year undergraduate students, enrolled in a semester-long course entitled "Didactics of Informatics" at the Department of Informatics and Communications, University of Athens, participated in this study. The 21 students were placed in seven groups (three students per group) (see section 2 for students' grouping). Students were asked to complete the LSQ and ILS learning style questionnaires outside of class. As an in-class activity during the session, students were given an individual concept map assignment; students were quite familiar with the concept mapping technique as during the course they had worked on several concept mapping activities. They were asked to act as tutors preparing a concept map using the COMPASS environment (free construction task, that is students are free to choose the concepts included in their maps) concerning the central concept "Computer Storage Units" for a high school class – a topic quite familiar to 4th year undergraduate students. This map would be used as a didactical tool during the corresponding course. According to the provided scenario, tutors should use as a resource the corresponding unit of the course book and take into consideration: the duration of the particular course (30 minutes), the knowledge level (average), age (13-14 years old) and prior knowledge of the students attending the course. Figure 1 presents an individual concept map. Then, students organized in groups and collaborated in constructing the group concept map for the particular concept. In this case, students were asked to act as tutors and collaborate with their colleagues for the same target. For the group map construction, students used COMPASS and consulted their individual concept maps constructed previously. Figure 2 presents a group concept map.

Level 1: Learning effectiveness at the individual level: Level of Individual Learning

1.1 Individual Achievement:
- 1.1.1 Number of correct beliefs (i.e. simple propositions & crosslinks) represented on individual concept map
- 1.1.2 Number of incorrect/false beliefs or unlabeled links or beliefs that are not able to be assessed, represented on individual concept map
- 1.1.3 Number of significant beliefs represented on individual concept map (significant beliefs are the correct or part of the correct beliefs according to the aims of the concept mapping task)

Level 2: Learning effectiveness at the level of the group: Level of Collaborative Learning

2.1 Group Achievement:
- 2.1.1 Number of correct beliefs represented on group concept map
- 2.1.2 Number of incorrect/false beliefs or unlabeled links or beliefs that are not able to be assessed represented, on group concept map
- 2.1.3 Number of significant beliefs represented on group concept map

2.2 Group Creativity: Number of correct beliefs presented on group concept map that are created in collaboration session

Level 3: Learning effectiveness as an interaction between individual and group achievement: Level of Interaction between Individual and Group

3.1 Individual to Group Transfer:
- 3.1.1 Number of significant beliefs that are transferred from individual to group concept map
- 3.1.2 Number of non-significant beliefs or false beliefs that are transferred from individual to group concept map

3.2 Rejection at Group Level:
- 3.2.1 Number of correct beliefs that are not transferred to group concept map
- 3.2.2 Number of significant beliefs that are not transferred to group concept map

Table 2: Levels and sublevels of the learning effectiveness analysis.

3.1 Evaluation Framework

In order to answer the research questions of this study we need to evaluate/analyse the students' individual and group work. To this end, we adopted Stoyanova and Kommers's (2002) and Khamesan and Hammond's (2004) approach, according to which learning effectiveness in collaborative concept mapping tasks may be measured on the basis of three levels: the level of individual learning, the level of collaborative learning and the level of interaction between individual and group. Following this approach, for each level, we used several sublevels aligned with the aims of our study. In Table 2, the levels and sublevels of learning effectiveness analysis are presented.

4 Results and Discussion

Each student constructed an individual concept map (see in Figure 1 the map constructed by Student3 of Group B) and a collaborative concept map with the other group members in the collaborative session (see in Figure 2 the map constructed by Group B), with a total of 7 group concept maps constructed. To answer the first research question "What are the effects of learning style on the students' group concept maps" – the level of individual as well as collaborative learning was evaluated. To answer the second research question "How the learning style or knowledge of an individual influence the group-interaction dynamics in terms of how s/he influences the final product?" - the level of interaction between individual and group was evaluated.

Learning effectiveness at individual level: level of individual learning. Learners' individual achievement was evaluated using three measures: total number of correct beliefs (i.e. propositions), total number of incorrect/false beliefs or unlabeled links/beliefs which could not be assessed, and total number of significant beliefs (see Table 3). The distinction between significant and non-significant beliefs was made as the concept map construction task was free (students could include any concept in their maps) and the scenario of the assignment had a specific target. To this end, as significant beliefs, we consider the propositions that fulfil the aims of the assignment for the central concept "Computer Storage Units", e.g. in Figure 1 both propositions "Magnetic Peripheral Storage Units consist of Zip Drive" and "Magnetic Peripheral Storage Units consist of Hard Disk" are correct whilst the second one is significant as the underlying information is aligned with the learning outcomes of the activity. Students' knowledge level was evaluated assigning weights on the above measures (2, -1, 4) based on the formula given below and assigned to one of the characterizations {Insufficient, Average, Rather Sufficient, Sufficient} (see Table 3):

Knowledge level = (total number of correct beliefs - total number of significant beliefs) * 2 – (1)
(total number of incorrect/false beliefs or unlabeled links/beliefs which could not be assessed)
* 1 + (total number of significant beliefs) * 4

As illustrated in Table 3, Student1 of Group A has included in his map 18 correct propositions, whilst 16 of these are also characterized as significant. Also, 2 beliefs represented on his map are false and 6 beliefs were not characterized as the particular links were omitted or/and the meaning of the propositions was vague. Student2 of Group A has included only 6 correct propositions in his map, which are also characterized as significant. Student3 of Group A has included 13 correct propositions in his map, which are also characterized as significant. Also, 7 beliefs were not characterized, as the meaning of the corresponding propositions was vague. Thus, the knowledge level of Student1 (Average) and Student3 (Average) of Group A seems similar and higher than that of Student2 (InSufficient) as they included more correct and significant concepts in their maps.

Learning effectiveness at group level: level of collaborative learning. The first way of measuring learning effectiveness at group level was in terms of the collaborative concept maps constructed, using the measures: *group achievement* (total number of correct beliefs, total number of incorrect/false beliefs or unlabeled links/beliefs which could not be assessed, total number of significant beliefs), and *group creativity* (total number of correct beliefs created during the collaborative session and not presented in either individual concept maps). Group performance was evaluated assigning weights on the above measures (2, -1, 4) based on the abovementioned formula (1).

As illustrated in Table 4, Group A concept map includes 23 correct beliefs and 19 of them are characterized as significant. Also, 3 false beliefs are represented on the map and the meaning of 2 beliefs is vague. During the collaboration session, more correct and significant propositions were constructed compared to the individual maps and 5 new correct beliefs were created (compare data of Student1, 2, 3 of Group A in Table 3 with data of Group A in Table 4). Interestingly, although the concept map constructed by Group F represents the most correct beliefs

compared to the other group maps, the performance of Group F is lower than that of Group B. This is due to the number of significant beliefs represented on the map, which is lower and the number of incorrect/false beliefs or unlabeled links/beliefs, which is higher than those of Group B.

Groups	Students	Individual Achievement			
		Total no of correct beliefs	Total no of incorrect/false beliefs or unlabeled links/beliefs not assessed	Total no of significant beliefs	Knowledge level
Group A	Student1	18	8	16	Ave
	Student2	6	0	6	Ins
	Student3	13	7	13	Ave
Group B	Student1	25	0	25	RSuf
	Student2	27	10	20	RSuf
	Student3	23	0	22	RSuf
Group C	Student1	11	0	10	Ave
	Student2	24	2	22	RSuf
	Student3	40	0	31	Suf
Group D	Student1	29	3	25	RSuf
	Student2	28	2	22	RSuf
	Student3	27	6	22	RSuf
Group E	Student1	33	0	24	RSuf
	Student2	16	3	15	Ave
	Student3	25	3	24	RSuf
Group F	Student1	28	2	12	Ave
	Student2	45	3	37	Suf
	Student3	12	3	12	Ave
Group G	Student1	15	1	14	Ave
	Student2	19	3	19	Ave
	Student3	26	5	20	RSuf

Table 3: Analysis of learning effectiveness at the individual level, where Ins: Insufficient, Ave: Average, RSuf: Rather Sufficient, Suf: Sufficient.

Groups	Group Achievement				Group Creativity
	Total no of correct beliefs	Total no of incorrect/false beliefs or unlabeled links / beliefs not assessed	Total no of significant beliefs	Group Performance	Total no of correct beliefs in collaboration session
Group A	23	5	19	79	5
Group B	24	1	24	95	6
Group C	21	0	21	84	0
Group D	21	2	19	78	1
Group E	21	3	20	79	2
Group F	27	3	19	89	0
Group G	24	1	18	83	1

Table 4: Analysis of learning effectiveness at the group level.

Three clusters of groups were identified based on group performance: Group B has the highest performance (see in column 5 of Table 4, Performance of Group B is 95), next are Groups F, C, G followed by Groups A, E, D. Group B has the highest performance, while Group D has the lowest. Although Group D has students with high knowledge level (see in Table 1 - all the students of Group D have Rather Sufficient knowledge level), the group performance is the lowest. Moreover, the creativity of Group D is also low. It may be that this group had students with extremely different style characteristics as two of the students have the same H&M learning styles (strong preference on the four styles) but quite different visual/verbal dimension (low verbaliser, high visualiser) whilst the third one had exactly the opposite H&M style (low preference on the four styles) compared to the others. It seems that high divergence of learning styles may difficult the group members in their collaboration.

Both Groups A and E have low performance (as group D). Students of these groups have similar H&M styles as in Group A all students have average preference on the four H&M styles, whilst Group E is a sole-Reflector group.

The similarity of students' H&M styles in both groups may stand as an obstacle for an effective collaboration to take place. Interestingly, Group B that also has students with similar H&M styles (average preference) but a mixture of visual levels and higher knowledge level has a higher performance. This difference between the performance of Groups A and B may be due to the mixture of visual levels and the higher knowledge level of the Group B students.

We should also notice that Groups A and B have the highest levels of group creativity although Group A has low performance. Their common characteristic, i.e. students with average preferences on the four H&M styles, may be an appropriate approach for grouping students based on their H&M style. We also notice that Groups C, F, and G have similar performance and students with a mixture of H&M styles. Among these groups, Group F has the highest performance. The particular group has students with a strong preference on three different H&M styles (1 Activist, 1 Reflector, 1 Theorist) and higher visual levels compared to Groups C and G. It may be that such a mixture of H&M styles combined with a mixture of visual levels and knowledge level is an effective approach for grouping students.

Learning effectiveness at group level: level of interaction between individual and group. The second way of measuring learning effectiveness at group level was in terms of the interaction between group and individual concept maps, with two measures of *individual to group transfer* (total number of significant beliefs transferred from individual to group map, total number of false or non-significant beliefs transferred from individual to group map) and *rejection at group level* (total number of correct beliefs not transferred to group map, total number of significant beliefs not transferred to group map). Thus, as illustrated in Table 5, the analysis of the interaction between individual to group achievement indicates that for Group A, Student1 (74%) and Student3 (53%) influenced mainly the group map as the number of significant beliefs that were transferred from their individual to group map was 14 and 10 (out of 19 – see *Total no of significant beliefs* of Group A in Table 4) respectively.

Groups	**Students**	**Individual to Group Transfer**		**Rejection at Group Level**	
		Total no of significant beliefs transferred from individual to group map	Total no of false or non-significant beliefs transferred from individual to group map	Total no of correct beliefs not transferred to group map	No of significant beliefs not transferred to group map
Group A	Student1	14 (74%)	1	4	2
	Student2	0 (0%)	0	6	6
	Student3	10 (53%)	2	3	3
Group B	Student1	14 (58%)	0	11	11
	Student2	11 (46%)	1	16	9
	Student3	18 (75%)	0	5	4
Group C	Student1	10 (48%)	0	1	0
	Student2	13 (62%)	0	11	9
	Student3	19 (90%)	0	21	12
Group D	Student1	9 (47%)	0	20	16
	Student2	16 (84%)	1	12	6
	Student3	13 (68%)	3	14	9
Group E	Student1	12 (60%)	0	21	12
	Student2	14 (70%)	4	1	1
	Student3	12 (60%)	0	13	12
Group F	Student1	12 (63%)	10	8	0
	Student2	18(95%)	3	25	19
	Student3	10 (53%)	0	2	2
Group G	Student1	14 (78%)	1	0	0
	Student2	12 (67%)	0	7	7
	Student3	16 (89%)	5	5	4

Table 5: Analysis of learning effectiveness in terms of the interaction between individual and group achievement.

Student 3 of Group B (see also Figures 1,2) has the highest impact on the group map (75%), as he transferred 18 significant propositions (out of 24 of Group B) to the group map. Note that, the propositions he transferred were all significant, whilst 5 correct propositions of his individual map were left out with 4 of them being significant (see in Table 3, the *Total no of correct/significant beliefs* of Student3 of Group B: 23/22). Also, Student 3 of Group C has a significant impact on the group map (90%). That student, although he transferred 19 significant propositions of his

individual map to the group map, other 12 significant and 9 correct beliefs were left out (see in Table 3, the *Total no of correct/significant beliefs* of Student3 of Group C: 40/31). It is also interesting to note that several students, such as Student2 of Group B (see Figure 2), managed to transfer their individual false beliefs in the group map.

Overall, in many cases learners with the same knowledge seem to influence differently the group map based on their visual/verbal dimension or knowledge level. Thus, students with greater impact on the group map (see Table 5) seem to have the highest visual levels and/or knowledge level. In more detail, in cases were the knowledge level of the students of a group is equal, those with the highest visual level seem to have greater impact on the group map, such as Student 3 in Group B, Student 2 in Group D. It may be that visualisers work better with graphical representations. In cases were the visual/verbal dimension of students is equal or among the students with the highest levels, those with higher knowledge level seem to have greater impact on the group map, such as Student 3 in Group C, Student 2 in Group F, Student 1 in Group A. In Group G where there is a slight difference among the visual/verbal dimension of the three students (2 medium visualisers, 1 high visualiser) and their knowledge level (2 Average, 1 Rather Sufficient); one of the medium visualisers with rather sufficient knowledge level (highest knowledge level among the students of the group) has the greatest impact on the group map. In Group E where the difference of the visual/verbal dimension of the students is great (1 low visualiser, 1 low verbaliser, 1 high visualiser), the high visualiser seems to have a greater impact on the group map although his knowledge level (Average) is lower than the others' (Rather Sufficient). Interestingly, the student with the greatest impact on a group map is a high visualiser with high knowledge level, e.g. see Student2 in Group F who has the greatest impact among all the students (95%) on the group map.

5 Conclusions and Future Research

In this pilot study we investigated the effects of learning style and knowledge level on group concept mapping and group-interaction dynamics. We analysed individual as well as group maps and we provide several data that could serve as valuable indications for accommodating individual differences in group formation especially for collaborative CM tasks. Based on our findings, the ideal group seems to be a mixture of learning styles including cases with average preference on the H&M styles (Group B) or strong preference on different H&M styles (Group F), a mixture of visualisers and knowledge levels. The least ideal group consists of students with extremely different styles or similar styles. Moreover, analysing the interaction between group and individual concept maps we provide evidence about the important influence of both the visual/verbal dimension and knowledge level in group-interaction dynamics. However, this investigation is the first step towards a comprehensive study of the impact of individual differences on group work in the context of web-based collaborative CM systems.

References

Cañas, A. J., Ford, K. M., Novak, J. D., Hayes, P., Reichherzer, T. R., & Suri, N. (2001). Using concept maps with technology to enhance collaborative learning in Latin America. The Science Teacher, 68, 49-51.

Coffield, F., Ecclestone, K., Hall, E., Moseley, D. (2004). Learning Styles and Pedagogy in post-16 learning: A systematic and critical review. London: Learning and Skills Research Centre. Available at: http://www.lsda.org.uk/files/pdf/1543.pdf

Felder, R.M., & Silverman, L.K. Learning and Teaching Styles in Engineering Education, Engineering Education, 78 (7) (1988) 674-681.

Gouli, E., Gogoulou, A. Papanikolaou, K. & Grigoriadou, M. (2004). COMPASS: An Adaptive Web-Based Concept Map Assessment Tool. In A.J. Canas, J.D. Novak and F.M. Gonzalez (Eds): Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain.

Honey, P. & Mumford, A. (1992). The manual of learning styles, Maidenhead: Peter Honey Publications.

Jonassen, D.J. (1992). What are cognitive tools? In P.A.M. Kommers, D. H. Jonassen, & J.T. Mayes (Eds.), Cognitive tools for learning, 1-6. Germany, Berlin Heidelberg: Springer-Verlag.

Jonassen, D.H., Grabowski, B.L. (1993). Handbook of individual differences: Learning and instruction, Hove: LEA.

Khamesan, A. & Hammond, N. (2004). Synchronous collaborative concept mapping via ICT: learning effectiveness and personal and interpersonal awareness. In A.J. Cañas, J.D. Novak and F.M. Gonzalez (Eds): Concept Maps:

Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain.

Luckie, D., Harrison, S. & Ebert-May, D. (2004). Introduction to C-TOOLS: concept mapping tools for online learning. Concept Maps: Theory, Methodology, Technology. In A.J. Cañas, J.D. Novak and F.M. Gonzalez (Eds): Proceedings of the First International Conference on Concept Mapping, Vol. 2, 261-264.

Soloman, B.A. & Felder, R.M. Index of Learning Styles Questionnaire (1999). Available: http://www.engr.ncsu.edu/learningstyles/ilsweb.html

Stoyanova, N. & Kommers, P. (2002). Concept mapping as a medium of shared cognition in computer supported collaborative problem solving. Journal of Interactive Learning Research, 13 (1/2) 111-133.

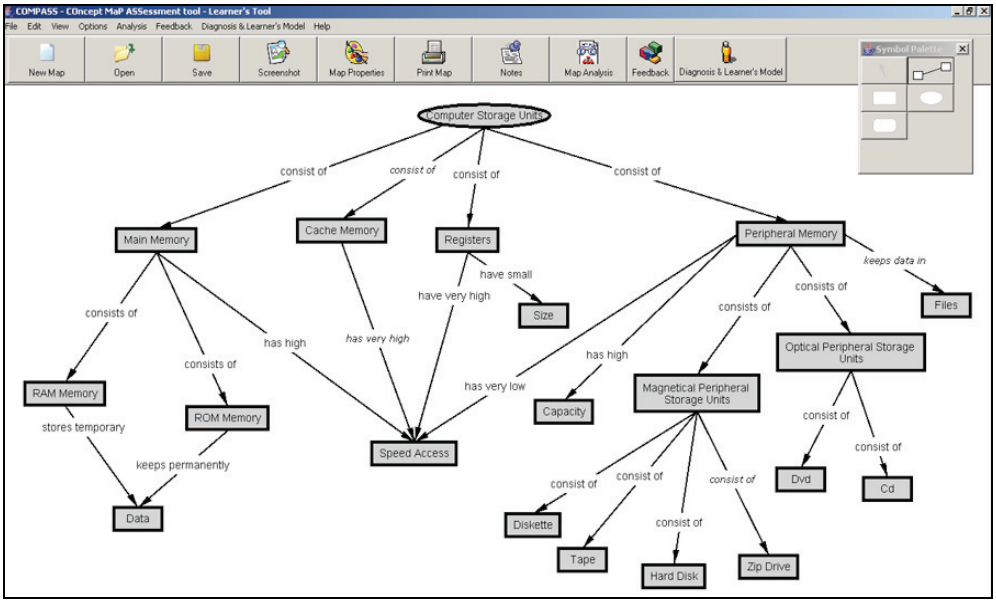


Figure 1. The concept map constructed by Student3 of Group B. It includes 23 correct beliefs with 22 of them characterized as significant. Although Student3 believes that "Computer Storage Units consist of Cache Memory", he didn't transferred it to the group map.

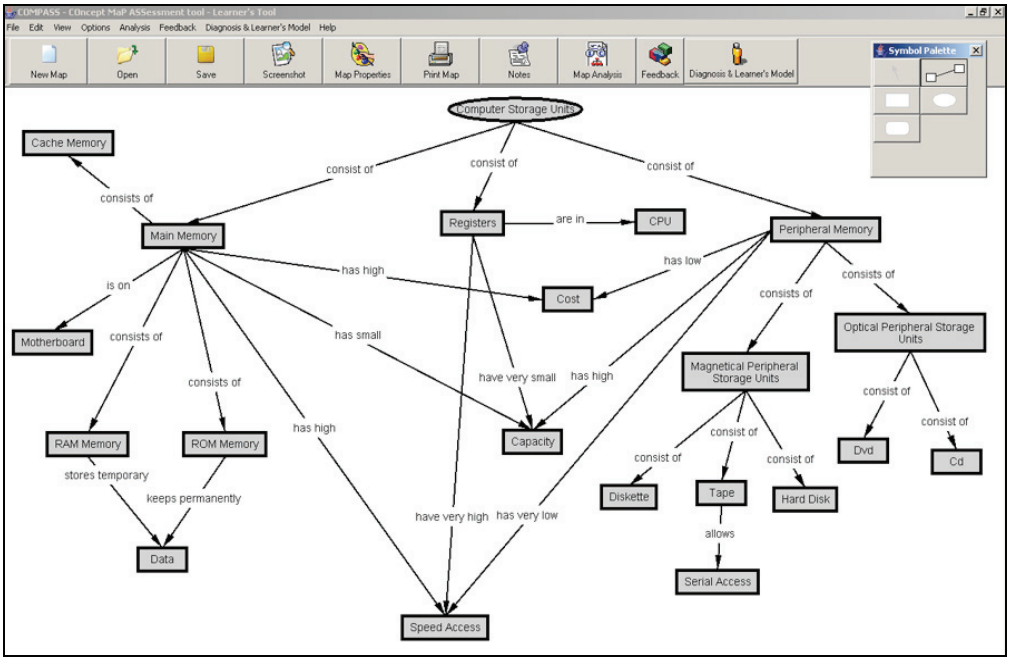


Figure 2. The concept map of Group B: includes 24 significant beliefs and the false belief "Main memory consists of Cache Memory" transferred from Student2's individual map.

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ADVANCING TEACHING AND LEARNING IN MEDICAL EDUCATION THROUGH THE USE OF CONCEPT MAPS

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Abstract. The purpose of this study was to investigate the ways in which the use of concept maps influenced the learning processes of third year internal medicine students in the context of medical education. Sixty-three students were taught to use concept mapping as a learning strategy at the beginning of their internal medicine rotation. The first and final concept maps created by these students were collected and scored. Results indicate that there was a significant difference in the concept map scores of students during their clerkship rotation. Implications for teaching and learning in medical education are drawn.

1 Introduction

According to Shulman (2005), "the *signature pedagogies of the professions* are not eternal and unchanging. Even though they seem remarkably stable at any one point in time, they are always subject to change as conditions in the practice of the profession itself and in the institutions that provide professional service or care undergo larger societal change" (p. 5). As such the practices of medical education are changing, creating multiple questions in the field. Is medical education preparing future practitioners for the changes in care delivery? Are medical students learning in ways that will facilitate their future clinical practice? Are there educational strategies that can be increasingly effective in the development of medical practitioners? Due to the rapid changes in the science of medicine and the need for future practitioners to remain competent in such an evolving medical environment, today's medical students should be encouraged to learn in a meaningful way and become lifelong learners. Meaningful learning, the ability to understand and relate relevant medical concepts by linking them to prior knowledge is of great formative value for junior medical students. Furthermore critical thinking and clinical problem solving are of significant importance in the education of future physicians. Despite attempts to foster new ways of learning, mainly seen in graduate medical education (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000), the development of new teaching tools has been limited due to difficulty in developing, delivering and assessing such strategies in undergraduate medical curricula. Nevertheless, the Association of American Medical Colleges (AAMC) has been concerned enough about this issue, that they have launched a project specifically to investigate the clinical education of medical students. AAMC (2001) states, "the Association has embarked on a number of programmatic activities designed to assist medical schools in their efforts to reform their curricula, and to improve the pedagogical approaches being used to promote student learning" (p. 1).

The purpose of this paper is to describe a study that investigated concept maps as a pedagogical approach used to promote learning with third year internal medicine students. In this study, concept maps were used as both a learning tool and an assessment approach. The intent of this investigation is to expand the understanding of educational strategies that can assist medical educators as they prepare future practitioners.

2 Literature Review

As the medical profession continues to change, so do the educational methods by which medical students are taught. West et al. (2000) acknowledge the need for alternative teaching and learning strategies that will enable medical students to retain vast amounts of information, integrate critical thinking skills and be able to solve a range of complex clinical problems.

Many literature sources support the utilization of concept mapping as a beneficial learning method (Novak, 1990; Pinto & Zeitz, 1997). Irvine (1995) recognizes concept mapping as a means to promote meaningful learning and as a metacognitive strategy. Concept maps demonstrate a student's mastery of a topic's attributes, relationships and for a greater development of holistic understanding (Marchand, D'Ivernois, Assal & Hivon 2002; Plotnick, 2001).

Concept mapping has been successfully used in education for a number of years (Novak, 1990). Several other health related fields have also used concept mapping as a successful learning tool. In nursing, concept maps have been used as an illustrative teaching/learning strategy, which allows the students to visualize the nursing process (Schuster, 2000). Beitz (1998) acknowledges that concept mapping can improve problem solving, clinical instruction and can be used to promote optimal learning of nursing theory and practice. At the Cornell University College of Veterinary Medicine concept maps have been used as teaching tools in order to facilitate the understanding of concepts more clearly and as a reflection of the students' learning (Edmondson & Smith, 1998).

Therefore, concept mapping has the potential to provide medical students with an additional educational tool in order to understand complex and vast amounts of required reading, and would allow for the student to demonstrate interrelationships of particular topics and show a holistic knowledge of this understanding. Since errors in practice are costly, meaningful learning strategies and tools are necessary for the development of accurate (diagnostic) reasoning processes.

2.1 Lifelong Learning

Meaningful learning, as defined by Ausubel (1968), links new knowledge with previous knowledge ultimately creating life-long learning. Life-long learning is promoted through concept mapping by the student's ability to not only create meaningful learning, but to transfer knowledge gained to future problems as well. Concept mapping facilitates the student's ability to organize information, assess existing knowledge gains, develop insights into new and existing knowledge and transfer knowledge to new experiences. To be competent professionals, medical students must become life-long learners (Pinto, 1997). According to Weiss and Levison (2000) in order to assist medical students to keep abreast with vast amounts of new information and become competent physicians, medical educators must teach the students life-long learning skills.

In many disciplines, particularly in the sciences, concept maps have been used successfully to promote meaningful learning and effective teaching. As a metacognitive tool, one advantage of concept maps is that concept maps can be used in most any discipline or with a variety of teaching methods (Edmondson & Smith, 1998). In medicine, meaningful learning is now recognized as a major goal amongst medical educators (Pinto & Zeitz, 1997). Therefore, concept maps have the potential to facilitate meaningful learning within medical education. However, although meaningful learning through concept mapping can be significant and stimulating, it is often difficult for teachers to move away from rote learning to meaningful learning (Harpaz, Balik, & Ehrenfeld, 2004; Novak, 1990).

2.2 Meaningful Learning Outcomes

As previously stated, the goal of concept mapping is to foster learning in a meaningful way (Novak & Gowin, 1984). Often the outcomes of this type of learning are varied and unpredictable. However, the literature cites three main concept mapping outcomes; to provide an additional resource for learning, to enable feedback and to conduct learning evaluation and assessments (Roberts, 1999).

2.2.1 Resources for Learning

As a resource for learning, concept maps allow the student to demonstrate their mastery of the concepts associated within a particular body of knowledge (Marchand et al., 2002). Concept mapping is a creative activity that fosters reflection into one's own understanding (Coffey, Carnot, Feltovich, Hoffman, & Cañas, 2003). According to Pinto and Zeitz (1997) concept maps can facilitate students' understanding of the organization and integration of important concepts. By connecting old and new knowledge, this type of learning clarifies knowledge, improves critical thinking and assists in completing missing knowledge (Harpaz et al., 2004).

From a student's perspective, concept mapping encourages them to think independently, produces more self-confidence and provides an increased awareness of making connections across different areas of knowledge. Teachers reported that concept mapping assisted students to become active learners and organize theoretical knowledge in an integrative manner or conceptual framework (Boxtel, Linden, Roelofs, & Erkens, 2002; Harpaz et al., 2004).

Laight (2004) designed a study to explore students' attitudes towards concept maps as an additional learning resource. Pre-prepared concept maps were integrated into traditional instructional methods. Developed questionnaires asked whether the concept maps were useful and also allowed for comments. A significant majority of the students reported that pre-prepared concept maps were useful to their learning. Even though no significant statistical association between the self-reported usefulness of the concept maps and a preferred learning style was shown, students did report an encouragement to think more deeply and noted an increased understanding of conceptual interrelationships. Therefore, according to Laight (2004) pre-prepared concept maps may offer alternative and innovative learning/teaching opportunities and methods in large classes and may promote teaching to multiple learning styles.

"Students and teachers constructing concept maps often remark that they recognize new relationships and enhance new meanings or, at least, meanings they did not consciously hold before making the map" (Novak & Gowin, 1984, p. 17). Concept mapping also allows for the students to reflect on their own (mis)understandings and take ownership of their learning.

Collaborative learning was explored in a study done by Kinchin and Hay (2000). Following the identification and themes of three major patterns of knowledge development (by analyzing individual student concept maps), the students of different knowledge patterns collaborated together. This study found that when the students of these separate knowledge structures collaborated together, more progress took place. Students who produced "low end" concept mapping structures benefited from students with "higher end" concept mapping structures, thus producing greater conceptual change.

Furthermore, in a qualitative study using concept maps performed by Boxtel et al. (2002) when students collaborated on a particular task, it was discovered that they communicated more effectively, leading to the co-construction of reason and meaning. Furthermore, the concept maps encouraged verbalization of questions, answers and assumptions allowing peers to communicate incorrect connections or links, creating a co-construction of meaningful learning.

2.2.2 Feedback

In relationship to feedback, concept mapping can assist the student in clarifying a topic and teachers can use maps to provide feedback and identify student misunderstandings (Roberts, 1999). According to Kinchin and Hay (2000) concept maps are seen as a communication tool between student and teacher which reveals the students' constructions of connections.

Edmondson and Smith (1998) performed a qualitative study that analyzed students' responses to the integration of concept maps as a teaching/learning tool. The majority of the students claimed that concept maps greatly facilitated their understanding. Almost one-half agreed that creating a concept map was an effective learning device. As a teaching method, the concept map provided the teacher with the students' errors or misconnects, thereby allowing the teacher to provide feedback and clarify content.

2.2.3 Evaluation Methods

Concept maps can be used as evaluation tools for identifying both valid and invalid learner thoughts and links. Concept maps can be used in formative assessments (where the teacher can assess the student's learning at a particular point) or summative assessments (to determine the student's understanding of a complete section or for a grade) (Coffey et al., 2003). Williams (2000) notes that concept maps can be used as an assessment for learning rather than an end process of learning. Concept maps are a useful tool for, "making the process of knowledge explicit" (p. 37). However, according to Roberts "because maps can vary greatly in style, a scoring method which suits the particular type of map must be chosen" (1999, p. 716).

Concept mapping was used as assessment tool in a case study completed by Williams (2004). In this case study, the student analyzed the role of a walk-in center nurse. The role was analyzed with evidence, a literature review, and a reflection of other walk-in centers. Throughout the study, the student followed specific criteria and guidelines. Feedback was provided consistently, according to how the mapping progressed. At the completion of the case study, the student had successfully demonstrated an understanding of evidenced-based practice. Therefore, when using

concept mapping as an assessment tool, the assessments should be meaningful to the students and reflect real situations in order to create meaningful and life long learning skills (Williams, 2004).

Concept mapping was also used in a pretest/posttest study done by West et al. (2000). Although concept mapping assessment scores did improve after course instruction, concept mapping assessment (CMA) scores did not correlate with final course or standardized test scores. According to West et al. (2000) "the absence of a positive correlation suggests that CMA measures a different knowledge characteristic than do multiple choice examinations" (p.1109) and therefore, concept mapping assessment has the potential to evaluate how students or residents organize and use knowledge in a way that traditional tests cannot. This type of assessment may also provide insight into why some residents score well on objective written examinations but have difficulty with clinical application.

As previously stated, concept mapping has the possibility to measure a student's evolving knowledge framework. According to Kinchin and Hay (2000) concept maps can reveal what each student knows and also can illustrate how the student understands and arranges knowledge in their individual minds. Finally, concept maps can provide teachers with insights into misunderstanding, misconceptions or common errors (Boxtel et al., 2002; Edmondson & Smith, 1998). In medical education, concept maps could provide a valuable tool to medical educators that reveal students' misunderstanding of concepts. These misunderstanding could lead to an identification of potential (patient) errors (West, 2002).

2.3 Concept Mapping and Medical Education

Currently, most medical students are enrolled in traditional curriculums that use rote learning strategies in their basic science courses (Pinto & Zeitz, 1997). However, with this methodology, educational deficits are being noted in clinical errors, including judgment and poor integration of theory and practice (Eitel & Steiner, 1999). It is imperative that medical education be astute in the development of problem-solving skills, particularly in the context of diagnostic reasoning. Finally, changes must also encompass how to approach and integrate the demand for vast and emerging information into the medical education curriculums. Therefore, medical education must seek alternative educational tools and strategies in order to produce successful outcomes. Clinical errors can be detrimental to all. Edmondson and Smith (1998) stress accurate diagnosis is critical to the practice of medicine.

Coles (1990; as cited in Edmondson and Smith, 1998) states that, "students need to be encouraged to recognize that merely understating what they are learning (deep-processing) is not in itself sufficient. They need to elaborate their knowledge; to build up more and more complex networks; to structure their knowledge" (p. 21).

Concept mapping can facilitate meaningful learning in medical students, residents and physicians. When used as a supplemental learning tool, concept maps can potentially promote deep learning in medical and biomedical science education (Laight, 2004). Concept mapping in the medical field allows the student to conceptualize a body of knowledge by identifying numerous cross-links between the concepts, thus serving as a useful tool for selecting and developing learning objectives regarding the topic (Weiss & Levison, 2000). Finally, concept maps can help form a bridge from medical school to residency training by integrating new knowledge from the residency program with the knowledge acquired during medical school (Pinto & Zeitz, 1997). Therefore, concept mapping could facilitate the process of medical students learning to learn and integrating new concepts into long-term memory.

Additionally, since evidenced-based innovative educational ideas have surfaced and concept mapping is a well-known learning aid and evaluation tool, many authors have called for a change in medical education. However, the attempt to change traditional curriculum has experienced strong resistance due to the paucity of concept mapping literature in the medical field and the limited literature regarding validity and reliability (Eitel & Steiner, 1999; Laight, 2004; Weiss & Levison, 2000; West et al., 2002). According to West et al. (2002) in order to evaluate developing knowledge, the structural features of the maps need to be incorporated into the thinking frameworks of resident doctors. Therefore, if medical education is to use concept mapping as an educational tool, then valid and reliable methods of concept mapping assessment measures are needed.

Although well-known as a successful learning aid and evaluation tool, medical educators rarely use concept mapping as a teaching/learning method. As such, the purpose of this study was to conduct more research on concept mapping in medical education and to promote awareness of this technique with empirical evidence.

3 Research Questions

From this literature review it is evident that concept maps can promote learning and changes in students' thinking in a variety of ways. Also concept maps have been used effectively in science education, math education, veterinary education, nursing education and engineering education. However, there has been limited application in medical education. As such, the following research questions are advanced to guide this inquiry:

1. How do concept maps impact the learning of third year medical students?
2. How do concept map scores of third year medical students change during their clerkship?

4 Methodology

This study used a mixed-methods design that investigated student learning through concept map change scores. Additionally, students completed a qualitative evaluation of their experiences learning with concept maps (reported elsewhere).

From July 2005 – October 2005, each group of third year medical students rotating through the internal medicine clerkship were taught to use concept maps. This involved the clerkship director spending approximately 1.5 hours teaching students about the underlying premise of learning with maps, steps in map construction, using CMAP tools to create the maps, and discussing the maps with students during their clinical rotation. In all, 63 students were included in the clerkship and this study.

Each student created three maps during the course of their clerkship. The maps were created around clinical problems, such as renal failure, congestive heart failure, etc. For the purposes of this study, the first and last maps were collected from each student. Points were awarded according to the scoring formula developed by Novak & Gowin (1984). Points were awarded for the subsumption of lower order concepts under higher order concepts, progressive differentiation of concepts, and the integrative reconciliation of concepts. Based on the scoring formula the students received points for creating propositional linkages and for the analysis and synthesis of concepts on their maps.

Reliability was established by obtaining two independent scores on each concept map. All researchers scoring maps were academic physicians specializing in internal medicine and trained to score concept maps. The correlation between the two independent scores was .73. Mean scores for the first map were then compared to mean scores of the third map for all students participating in the study. A dependent t-test was used for these comparisons.

5 Results

Study results indicate that concept maps were an effective learning strategy for medical students in their third year clerkship rotation. Figure 1 depicts the concept map of one student at the beginning of their internal medicine rotation and Figure 2 depicts the final map of the same student. What these figures demonstrate is the growth in concept differentiation and the development of a more sophisticated system of cross links.

Data analysis (Table 1) demonstrates a group mean of 71.711 on the first concept map and 94.09 on the final concept map of the clerkship rotation, for a difference of 22.38. The t-value comparing the first to final map was –4.1773 (p=.0001). The data indicate a statistically significant difference between the first and final map scores of the internal medicine clerkship rotation.

Variable	No. of Cases	Mean	Difference
First Student Map	63	71.71*	22.38
Final Student Map	63	94.09*	

P value * = .0001

Table 1. Changes in Concept Map Scores over Third Year Clerkship

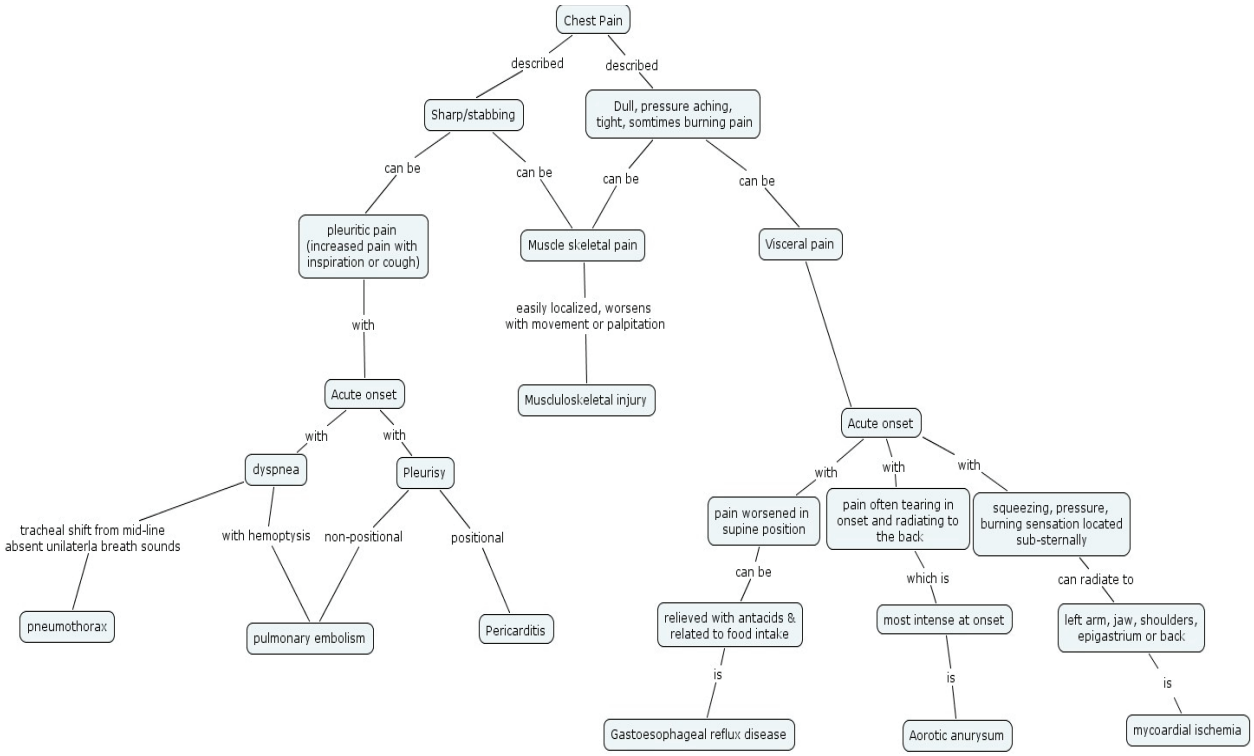


Figure 1: First Map of Internal Medicine Rotation

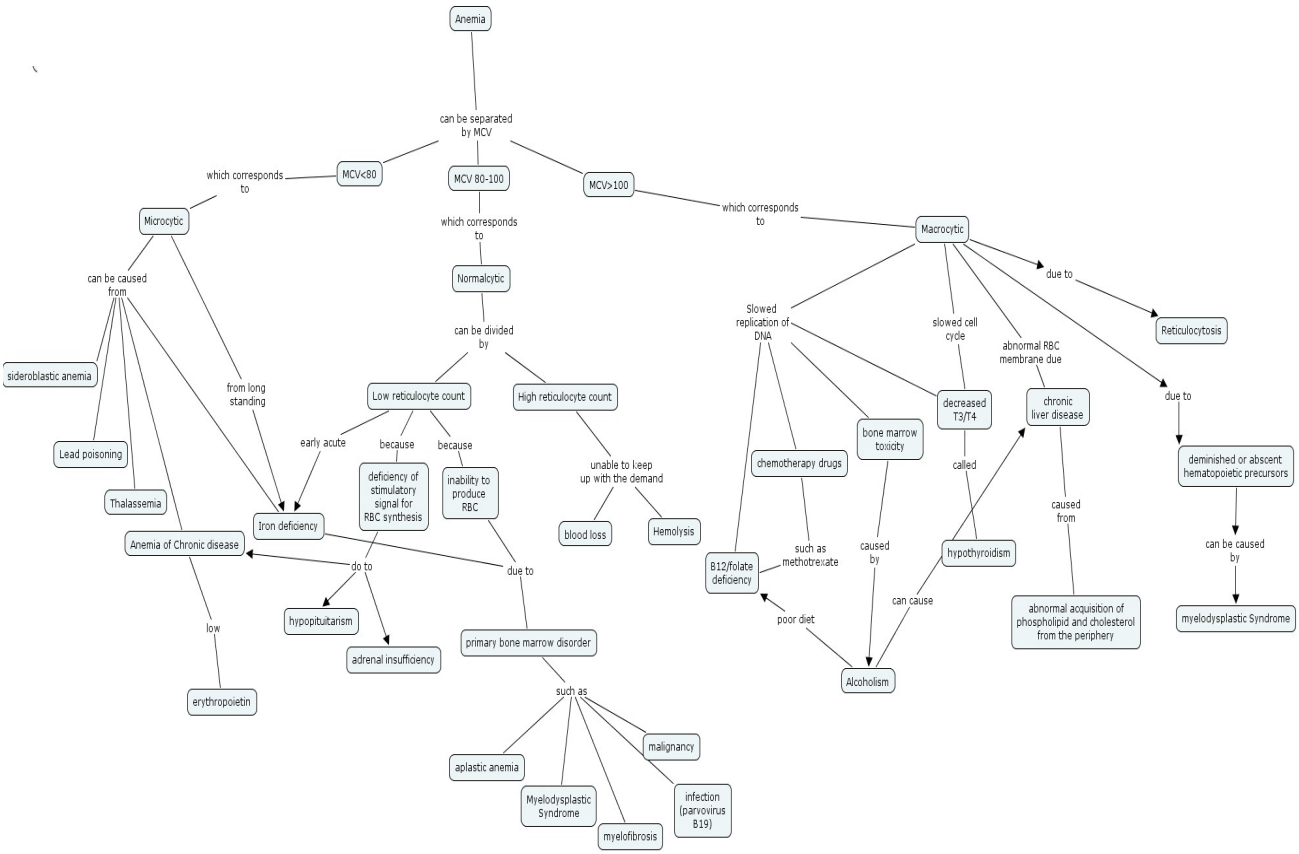


Figure 2: Final Map of Internal Medicine Rotation

6 Discussion

Results of this study indicate that using concept maps with medical students facilitated learning during the clerkship rotation. The findings from this research support previous work on concept mapping (Novak, 1998; Novak & Gowin, 1984). What is unique to this study is the application of concept maps as a tool to foster meaningful learning among third year medical students. Their ability to advance their learning, understanding, and thinking through the use of concept maps over a two-month clerkship rotation is an important step in teaching medical students new pathways to learning. It also demonstrates an increasing ability to think critically and to relate relevant medical concepts using a completely new method, which is an extremely important proficiency for junior medical students.

Additionally, in teaching the students how to do concept maps, it became clear that not only did these students not understand their own learning processes, but they were resistant to change learning strategies that had worked for them in the past. Once these students understood that the maps had the potential to support their learning in the clerkship by linking their theoretical knowledge to their clinical practice, they tended to be more interested in the mapping process. They began to see the maps as a way to understand their patients and the patients' disease process.

7 Implications for Medical Education

This study has numerous implications for medical education. First, study results indicate that medical students were able to use concept maps to understand content in new ways and to create maps that linked theoretical material to clinical practice. The implication here is that concept maps, as a tool, may assist medical students in advancing their skills in critical thinking, diagnostic reasoning and patient assessment. The ability to apply theoretical knowledge in a clinical setting is an advanced thinking skill that needs to be specifically developed in medical students. The change in concept map scores in this study indicates that this process took place, but additional research is needed on exactly how the maps facilitated the process of applying theoretical knowledge in the clinical context. In addition, more research is needed on how concept maps facilitate critical thinking, diagnostic reasoning and patient assessment.

Second, this study implies that faculty in medical education could benefit from learning about concept mapping as a teaching/learning strategy. One of the biggest challenges for faculty in medical education is changing teaching approaches to incorporate what we know about student learning. Using concept maps necessitates that faculty have a good understanding of various learning theories and approaches and the ways in which maps represent students' thinking. To use this strategy effectively faculty need to be able to create their own concept maps that demonstrate subsumption, progressive differentiation and integrative reconciliation (Novak & Gowin, 1984). This involves learning how to construct concept maps, and learning how to use them in teaching. To use this approach faculty development programs may provide the needed assistance.

Finally, to use mapping faculty need to be willing to foster an approach to learning as meaning construction. This means that the focus of clerkships shifts from teaching and presenting information to learning and creating meaning. This is much more than a change in how we talk about teaching and learning. It is a fundamental shift in teaching approach, faculty role, student responsibility and assessment of learning. As such, the role of the faculty member shifts from content expert to facilitator of learning. Often this is a demanding change that requires a new way of thinking about teaching and learning.

In summary, this study demonstrated that concept maps were an effective learning strategy for residents in their third year clerkship. Concept maps scores significantly improved over the course of the two-month rotation, leading to more effective learning outcomes. More research is needed on how the maps link to other aspects of medical education and faculty development.

References

Association of American Medical Colleges. (2001). *The AAMC Project on the Clinical Education of Medical Students*. Washington, DC Association of American Medical Colleges.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Reinhart and Winston.

Beitz, J. M. (1998). Concept mapping: Navigating the learning process. *Nurse Educator*, *23*(5), 35-41.

Boxtel, C. V., Linden, J. V., Roelofs, E. & Erkens, G. (2002, Winter). Collaborative concept mapping: Provoking and supporting meaningful discourse. *Theory into Practice, 41*(1), 40-46.

Coffey, J. W., Carnot, M. J., Feltovich, P. J., Feltovich, J., Hoffman, R. R., Cañas, A. J., & Novak, J. D. (2003). *A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support* (Technical Report submitted to the US Navy Chief of Naval Education and Training). Pensacola, FL: Institute for Human and Machine Cognition.

Edmondson, K. M., & Smith, D. F. (1998). Concept mapping to facilitate veterinary students' understanding of fluid and electrolyte disorders. *Teaching and Learning in Medicine, 10*(1), 21-33.

Eitel, F., & Steiner, S. (1999, September). Evidence-based learning. *Medical Teacher, 21*(5), 506-513.

Harpaz, I., Balik, C., & Ehrenfeld, M. (2004, April-June). Concept mapping: An educational strategy for advanced nursing education. *Nursing Forum, 39*(2), 27-30, 36.

Irvine, L. M. (1995). Can concept mapping be used to promote meaningful learning in nurse education? *Journal of Advanced Nursing, 21,* 1175-1179.

Kinchin, I. M., & Hay, D. B. (2000, Spring). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research, 42*(1), 43-57.

Laight, D. W. (2004). Attitudes to concept maps as a teaching/learning activity in undergraduate health professional education: Influence of preferred learning style. *Medical Teacher, 26*(3), 229-233.

Marchand, C., D'Ivernois, J. F., Assal, J. P., Slama, G., & Hivon, R. (2002). An analysis, using concept mapping, of diabetic patients' knowledge, before and after patient education. *Medical Teacher, 24*(1), 90-99.

Novak, J. D. (1990). Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science, 19,* 1-25.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

Pinto, A. J., & Zeitz, H. J. (1997, June). Concept mapping: A strategy for promoting meaningful learning in medical education. *Medical Teacher, 19*(2), 114-122.

Plotnick, E. (2001). A graphical system for understanding the relationship between concepts. *Teacher Librarian, 28*(4), 42-45.

Roberts, L. (1999). Using concept maps to measure statistical understanding. *International Journal of Mathematical Education in Science and Technology, 30*(5), 707-717.

Schuster, P. (2000). Concept Mapping: Reducing clinical care paperwork and increasing learning. *Nurse Educator, 25*(2), 76-81.

Shulman, L. (2005). The signature pedagogies of the professions of law, medicine, engineering, and the clergy: Potential lessons for the education of teachers. Presented at the National Research Council Center for Education, February 6-8, 2005, Irvine, CA: Retrieved March 29, 2006 from http://hub.mspnet.org/index.cfm/11172

Weiss, L. B., & Levison, S. P. (2000, November). Tools for integrating women's health into medical education: Clinical cases and concept mapping. *Academic Medicine, 75*(11), 1081-1086.

West, D. C., Park, J. K., Pomeroy, J. R., & Sandoval, J. (2002). Concept mapping assessment in medical education: A comparison of two scoring systems. *Medical Education, 36,* 820-826.

West, D. C., Pomeroy, J. R., Park, J. K., Gerstenberger, E. A., & Sandoval, J. (2000, September 6). Critical thinking in graduate medical education: A role for concept mapping assessment? *Journal of the American Medical Association, 284*(9), 1105-1110.

Williams, M. (2004, November 10). Concept mapping - A strategy for assessment. *Art and Science, 19*(9), 33-38.

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AN AUTHORING CONCEPT MAPPING KIT FOR THE EARLY CHILDHOOD CLASSROOM

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Abstract. This paper presents an Authoring Concept Mapping Kit that enables preschool children to verbally add meaning to symbolic representations. Building on the prior knowledge and strengths of the users, children and teachers, the Kit is comprised of tangible materials familiar to the early childhood classroom, with the addition of low cost, hand-sized, voice-input devices. Preschool teachers encourage their students to concept map with symbols as a way to overcome illiteracy. However in practice unlabeled symbols allow room for map misinterpretations, concepts cannot be distinguished from propositions, abstract concepts cannot be introduced, and linking phrases cannot be inserted. Testing outcomes from a pilot study performed in an urban Australian preschool with 4-to-5 year olds demonstrates the Kit effectively addresses these problems.

1 Introduction

This paper presents the research for, development of, and the results of a pilot test of an Authoring Concept Mapping Kit (the Kit) for the Early Childhood (EC) classroom. Developed using child-centered design methodologies the Kit is a knowledge representation tool that responds to the needs of teachers and children in the classroom. Nine 4-to-5 year olds from an Australian urban preschool were observed while they used the Kit during free-play time and the performance of one of those children, a 5.6-year old, is discussed. Due to the school's operating philosophy, it was not possible to test children's ability to concept map, as defined in Novak's literature. Therefore their ability to independently make knowledge explicit with the Kit was tested instead. The results of the study showed the children were able to 1) label symbolic representations verbally for disclosing conceptual and propositional meanings, 2) manipulate concepts to show reading direction, and 3) display autonomous behavior. An unexpected outcome of the pilot was the high engagement levels three of the nine children presented while interacting with the Kit. They spent more than an hour in the overall activity, which included picture reading, discussion, and knowledge representation. This result may have implications for the long-term success of the Kit as an educational tool.

2 Background: The Kit as Part of a Doctoral Study

Novak (1998) states that concepts can be labeled with words as well as symbols such as %, +, etc. Also Novak and Wandersee state that young children may quickly learn how to make good concept maps since they haven't yet been exposed to years of rote-learning (1990 in Novak, 1998: 31). These authors theorized, but have neither researched children's use of symbols when labeling concepts, nor their ability at concept map making. However, for more than a decade, growing communities of experts within Early Childhood (EC) have been exploring strategies and adaptations for children to concept map with symbols. Novak and Wandersee's claims and the underlying constructionist theories of this knowledge representation tool are the driving forces behind their interest. In addition the experts also believe concept maps can help the development of young children's learning-how-to-learn skills (Figuereido et al., 2004; Mancinelli et al*.,* 2004; Perez Cabani *et al.,* 1992) and that could be more powerful than clinical interviews and drawings in disclosing children's knowledge (Mancinelli et al., 2004). My doctoral study involves the investigation of the development of an age-appropriate concept mapping tool that may allow for the testing of such claims.

While most researchers within this area have an educational or psychology background, a design perspective underpins the outcomes of this research. I argue that the Design discipline provides an alternate way of approaching the issue as well as constructing possible solutions. My approach has been informed by an analysis of current concept mapping practices in the EC classroom, the learning goals articulated by the teachers, and the tools currently used to achieve those goals. I then compared that analysis with the underlying theory of concept maps. The overlaps and gaps found led to a design method for introducing concept mapping into the classroom. The method is informed by user-centered, and inclusive design philosophies as articulated by Keates and Clarkson (2003) and Norman

(1999). I take up the position that by knowing your users, by understanding their environments and true needs, it is possible to design learning tools that will empower them.

My analysis of the reports of Figuereido et al., (2004), FOD (2004), Merida (2001-2002) and others uncovered the functional curriculums and the children's developing cognitive and literacy skills as major barriers impeding the systematic use of concept maps in the EC classroom. From this I claim that by solving the literacy barrier it will be possible to effectively investigate the developmental ones. Due to illiteracy preschoolers are unable to add meaning to symbolic representations as well as create, and manipulate abstract concept words autonomously. The Kit offers solutions to these problems by enabling concept labeling with voice-input, and too, is pivotal to the investigation and testing of the claim. While I do not argue that it is the answer to how we make concept mapping available to preliterate children, I do argue that it offers a starting point, a way of be able to undertake further research into the kind of concept mapping tools and strategies that are appropriate for use at this level.

3 From Symbol-based Maps to Concept Maps: How to Make the Leap

To overcome barriers presented by children's illiteracy and other developmental limitations, teachers have developed playful metaphors and representation tools that allow their young students to represent meanings in the form of simple symbol-based concept maps (see for example Badilla, 2004; Figuereido et al., 2004; Merida 2002; Mancinelli et al., 2004; Perez Cabani et al., 1992). Their objective appears to be the stimulation of children's critical thinking skills as well as the social interactions among peers. Symbols in the form of drawings, toys, and woolen threads are used to represent concepts or conceptual relationships. The connecting lines are maintained but the linking phrases are not introduced, as it is difficult to represent with visuals. The goal is to make the map-making process hands-on and meaningful to them by incorporating familiar languages (Badilla, 2004; Figuereido et al., 2004; Merida 2002; Mancinelli et al., 2004; Perez Cabani et al., 1992). While such approaches have shown to be of educational value, they do not conform to Novak's definition of concept maps and, as such, raise new problems. Unlabeled symbols 1) allow for map misinterpretations, 2) prevent the introduction of abstract concepts, and 3) do not accommodate the insertion of linking phrases.

Novak (1984) claims that the power of concept maps relies on the template elements, which means that the absence of any one of the elements affects the mapping process and the later interpretation of it. He also claims that the linking phrases in the map are what make his technique a meaningful learning activity. This is based on the understanding that people are able to see the linking phrases to interpret how the concepts within the map are related to each other. Meaning negotiation and representation of organized knowledge, which are concept maps key characteristics, depend heavily on these components. Yet if we agree with Novak's logic then the absence of linking phrases and/or concepts means that there is no way of accessing the level of the children's understanding. Finally, if we accept that the gap produced by the use of symbols lies in that impossibility, then a tool that enable children to add concepts and linking phrases with spoken language may provide a way forward. Since preschool children communicate what they know with visual and spoken language.

It can be understood from the preceding argument that the absence of written words limits knowledge externalization and what can be represented or discussed during the mapping process. Merida (2002) and Perez Cabani et al. (1992), who have investigated the problem, argue that is not really the resulting map that is important, but what the mapping process involves: meaning negotiation, collaboration, and training of critical thinking skills such as clustering, hierarchy. While their reasoning is not rejected, this paper does argue that such experiences can be made much richer and more effective if the mapping tools employed provide components that facilitate autonomous behavior and knowledge "explicitation" or in other words make the representation process explicit. I would argue that as children become autonomous map-creators, abstract content can be introduced, and as a consequence of this, a broadening of the content of areas under study becomes possible.

4 Design Characteristics of the Kit

Symbol-based maps support the development of clustering skills and hierarchy (Perez Cabani et al., 1992). But for reaching the three conditions of meaningful autonomous learning - language relatable to the learner, ability to access prior knowledge, and wanting to learn (Ausubel, 1968 in Novak, 1998), the current teacher tools for concept

mapping need re-designing to give full ownership of the authoring to the child. For this reason the Kit was developed to support children at concept labelling by enabling the use of multiliteracy (verbal, symbolic and/or emergent writing skills). It is comprised of concrete materials familiar to the preschool setting, such as magnetic and Velcro strips, markers, pens, colour pencils, construction paper, a write-and-wipe magnetic board, and incorporates voice chip recorders. These are low cost, hand-sized voice-input devices that can be recorded onto and played back many times. Figure 1 shows images of the components.

The Kit:

- *Brings autonomy to the children's mapping process* as it allows room for self-idea exploration, which in turn, may increase intrinsic motivation. It is widely known that good authoring tools require minimum teacher assistance in the making process, but lots of facilitation in the understanding of the topics and overall activity performance.

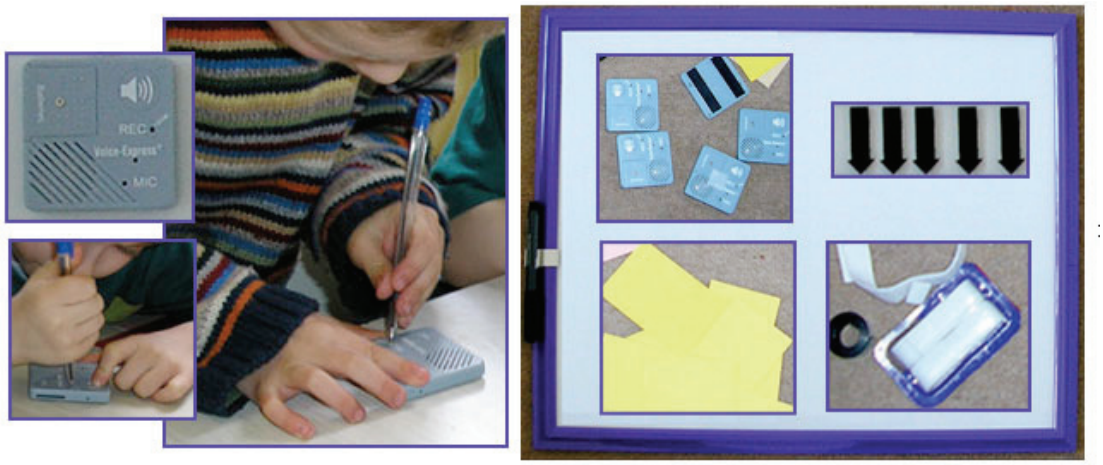


Figure 1. The Authoring Concept Mapping Kit

- The voice-recorders *make the children's knowledge explicit* by allowing them to verbally add meaning to symbolic representations, include abstract concepts and linking phrase. In current concept mapping practices, for disclosing meaning of images, teachers interview the children (Figuereido et al., 2004; Merida, 2002; Mancinelli et al., 2004) and most times annotate their maps with the answers given (Merida 2002; Mancinelli et al., 2004). With the Kit teachers neither require interviewing the children nor annotating the maps for the purpose of disclosing drawing meaning.

- *May facilitate teacher instruction* by providing them with resources adaptable to different mapping situations. It aims at enabling the teacher to diversify the range of strategies and the themes to explain concept maps or other mapping techniques to the children. The proposed design is open-ended and flexible. It is expected that the children and teachers add their own signature and ideas to improve the making process.

- *Facilitates sharing, manipulation, and preservation* because the pieces are easy shareable, removable and replaceable. The children can draw on the board; use post-it or construction paper of any kind. Connections can be either represented with a marker or the arrows provided. The magnetic board size delimitates space for mapping and the elements placed on it can be modified and revisited as desired. Whatever is produced during the session can be kept until next session or for as long as teachers and children want to keep it. The Kit materials make an abstract process less abstract. By making it look like a manipulative, we attempted giving the illusion that the concepts can be grasped and touched.

- Equips children with materials that not only speed up the mapping process but also *supports their developing cognitive and motor skills*. Some of the developing skills identified are limited memory retention (short attention span), conceptual development and self-regulation. Knowing-how to use the Kit responds to such limitations and

is facilitated by the familiarity of the components; therefore the tool learning curve is low as the children can explore the different parts.

5 Pilot Field Study

Nine children, from an Australian urban preschool, aged 4 to 5 were observed in their natural setting. While I worked with the whole class, 25 children in total, I am only permitted to report on 9 of these. The children interacted with the Kit during free-choice playtime for 6 sessions of 1½ hour each. The research was seeking to identify if (and to what extent) children could independently make knowledge explicit. The knowledge was to be made explicit using the Kit by labeling symbolic representations with the voice-recorders and showing reading direction with the arrows. Labeled symbols helped to distinguish concepts from propositions, identify abstract concepts, and what relationships were formed between concepts using linking phrases. All of these elements in sequence will allow the teacher or researcher to interpret the concept map.

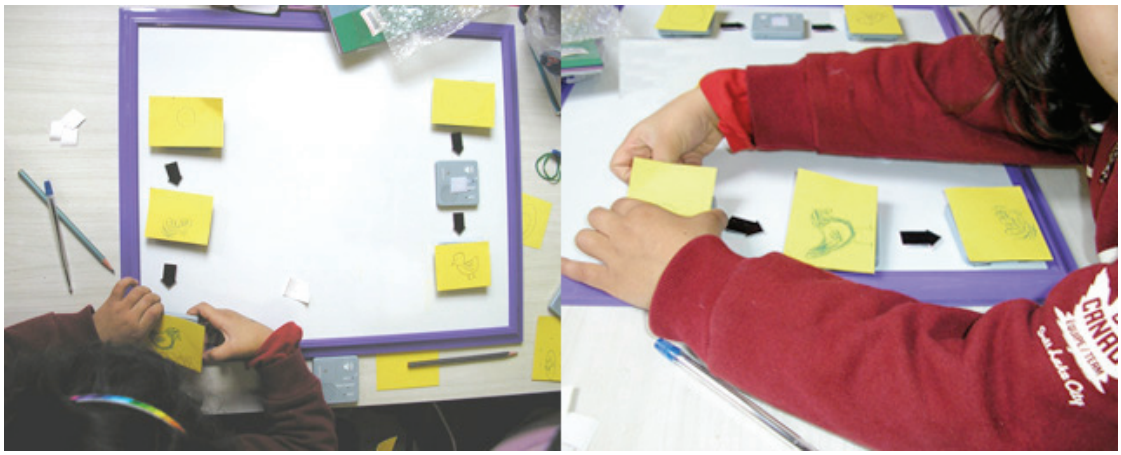


Figure 2. (a) Working on the conceptual relationship "the egg is in the stomach. (b) Working on the concept "egg".

The teacher/director of the school facilitated the interactions, gave me suggestions on how to work with the children and information about their background, but did not intervene in the process. Experiential learning is her teaching approach: based on the children's needs and interests, identified through observation, she presents the children with tools that will stimulate and promote their learning. Concept maps had not been of interest to her, as she saw them as being contrary to her teaching philosophy: she did not believe in telling children how-to-do things, rather she preferred them to explore their world. However she was interested in observing how the children would interpret the Kit. Because of this situation, the inexperience of the facilitator (paper author) in Early Childhood methodologies and lack of familiarity with the students' background, the children were neither instructed on Novak concept maps nor assessed on concept acquisition. The methods approved for data collection were participant observation, audio recording of the sessions, photography of the working process and the children's work, plus anecdotal notes.

In each of the 6 sessions different strategies were trialed for engaging children in concept mapping. Four out of the six sessions they were invited to perform a concept mapping foundational activities such as proposition and two-level map making. Their performance was poor, possibly due to the inexperience of the facilitator and the heavily directed character of the interactions with which they were unfamiliar. However by contrast, in session 2 and 5, the children responded positively to the material presented, maybe because it encouraged independent behavior, and built on their prior knowledge and interests. A brief summary of session 2 is presented together with transcripts of the knowledge representation activity - KRA of a 5.6-year old. This is the only child I can report on here, as the other two children were not approved to participate in the study.

In session 2, three children agreed to play. The facilitator invited them to read and discuss the pictures of the illustrated book *The Egg* (Mettler et al., 1990), and to use the Kit (or The Thing as the children named it) to make a

story of what they remembered from the reading. The book was chosen based on the children's interest and prior knowledge. The session was structured in three stages: reading and discussion (group activities) and KRA (individual activity). The facilitator paced the interactions, stimulated discussion, prompted questions, demonstrated how to make a story with paper cards, the voice-recorders, the arrows, and provided direct support in the making at children's request only. Each child was to place on the magnetic board self-created, voice-labeled symbols representing ideas from the book and use the magnetized arrows to show reading orientation.

The 5.6-year old engaged in the activity for 77.3 minutes (reading: 21.9, discussion: 10.3, KRA: 45.4 minutes). During KRA, the child worked independently during the session; asked questions; created symbols and voice-recorded meanings in the form of concepts (egg, the egg) and conceptual relationships (the egg is wet, the egg is dry, etc); and connected the concepts and/or propositions (formed by symbols attached to recorded voice-recorders) with arrows to show reading orientation. See figure 3 for completed story in map form. The following transcript excerpts give example of just described. Al and Glo are the aliases for the child and the facilitator respectively, [undisclosed] appears when the dialogue involves children out of the study and [inaudible] when the audio is unclear. Vrec is the abbreviation for voice-recorder.

Al is voice-recording by herself, first try

48.7min *Al:* *the egg is in the chicken's tummy!* [Voice-recording]
Al: *the egg is in the chicken's tummy!* [Voice-recording]
Glo: *[undisclosed]*
Al: *It's just saying the egg, the egg, it's just saying the egg*
Glo: *You said the egg*
Al: *No, I said the egg in the tummy [inaudible] says the egg*
Glo: *Say it again until you have it right* [meaning to try voice-recording again]
Al: *[inaudible]*
Al: *I said it [inaudible] times*
Glo: *Do it again until you have what you want* [motivating the child to continue trying]

From 49.4min to 52.7min the facilitator is working with two other children while Al is labeling (voice-recording) her drawings independently. She does not ask questions or request for help. In the background, the facilitator can also hear Al pushing, playing back the voice-recorder to disclose the sequence arrangement.

49.4min *Al:* *the egg is in the stomach* [voice-recording]
Al: *the egg is in the stomach* [voice-recording]
Vrec: *the egg is in the stomach* [playing back what's been voice-recorded]
Glo: *[undisclosed]*
Glo: *[undisclosed]*
Al: *eggs are cracking* [voice-recording a new idea]
Vrec: *eggs are cracking* [playing back what's been voice-recorded*]*

52.7min *Vrec:* *Egg*
Vrec: *The egg is in the stomach*
52.9min *vrec:* *The eggs are cracking*

The facilitator checked on Al: together revisited what has been recorded so far.

53.3min *Glo:* *How are you doing? Al, how is it going?*
Al: *I already did [inaudible]*
Glo: *You already did and how is the story going there?*
Al: *[inaudible]*
Vrec: *egg*
Glo: *how the story goes?*
Al: *"egg", "the egg is in the stomach", "the eggs are cracking"*
Glo: *So, the egg is in the stomach and the eggs are cracking? [Inaudible] that's a very good one!*

From 56.2min to 66.9min Al continues working independently. Again in the background from 63.3 min to 66.9 the facilitator can hear her voice recordings playing back as she pushes them.

63.3min Al: *the chicken is dry* [voice-recording*]*
64.7min Al: *the chicken is wet* [voice-recording]
64.8min Al: *the chicken is wet* [trying to voice-record again]
65.0min Al: *the chicken is wet* [trying to voice-record again]
66.2min Al: *egg* [voice-recording]
66.9min Al: *a [inaudible] with watery stuff that used to be inside the egg*

Al requests for arrows

69.5min Al: *I need those pointy things*
Glo: *You need a pointy… what do you need? A pen? Tell me sweetie… Ah! Pointy things. How many?* [She was meaning arrows]
Glo: *[undisclosed]*
Glo: *You need how many?*
Al: *Three*
Glo: *Three*
Al: *Actually, umm*
70.7 Glo: *Remember, Al, that you are making a sort of a story that other people can understand what are you saying*
Glo: *Is that enough?* [Referring to the arrows]
Al: *I made three stories* [meaning three propositions]
Glo: *That's very good*

[Facilitator continue working with other children]
71.4min Al: *I made all these ones*

[Facilitator continue working with other children]
71.8min Al: *I'll do the whole. I'll do my my little story. I want to read my little story*
Glo: *I am gonna do this* [meaning finish something] *and then you can tell me your story*

6 Conclusions

This mapping experience indicated that the child was able to undertake concept representation, organization and manipulation. After been demonstrated how to use the Kit, the 5.6-year old could autonomously made conceptual knowledge explicit: added meaning to symbols and linking phrases as part of the conceptual relationship formed; could represent abstract concepts; and changed symbol labels during the process (e.g. replaced *the egg is in the chicken's tummy*, with *the egg is in the stomach*). In figure 2(a) the child has a sequence arrangement *egg-→ the eggs are cracking -→ the eggs is in the stomach*. In figure 2(b) she has changed the order to *egg -→ the egg is in the stomach -→ the eggs are cracking*. This is an example of autonomous knowledge organization.

Overall, the results are positive in regard to preschool children's ability to undertake autonomous knowledge representation processes and the facilitative possibilities that this assistive tool offers to that process. As a broad conclusion, the Kit itself has been designed and tested and it is ready to be applied in any EC classroom. Now preliterate children can have easy access to a tool that makes them the owners of their knowledge "explicitation" productions. Its usefulness in terms of teaching is that teachers, by evaluating these productions, may be able to make a judgment in regard to conceptions and misconceptions of the children. An unexpected outcome was the children's level of engagement. Al worked on the activity for 77.3 minutes and spent more than 45 minutes working individually during KRA. The two children from session 5 also spent 66.5 minutes in the whole activity and 44 minutes on their individual KRAs. These values are even more impressive if we consider that all was performed during free-play time.

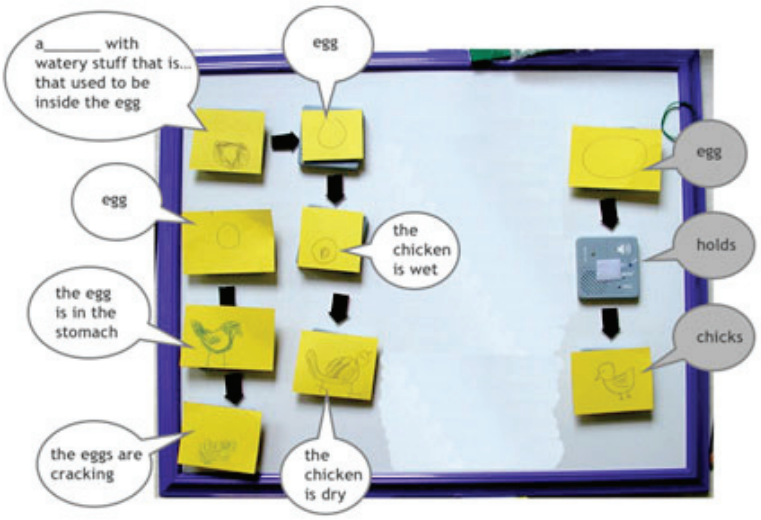


Figure 3. (Left board side) the 5.6-year old story in map form, (Right board side) the sample proposition done by the facilitator

Open-ended tools that enhance hands-on experiences are understood in this context, and relate to the theory of child development and strategies for stimulating thinking. The Kit is sufficiently intriguing and attractive that teachers who have been exposed to it want to try it, even though concept mapping as a learning strategy is still not employed in Australian preschools. Work needs to be done to convince Australian teachers of the benefit of such an approach. Conversations with the teacher involved in this research suggest that the use of voice-input devices might be of benefit in classroom learning/activities currently being used. As well teachers present at the author's talk at the Children of the New Millennium Conference (Gomez, 2005) showed a great deal of interest. For those countries and teachers in the rest of the world who are using concept mapping, this research has produced a tool that might help overcoming one of the most significant barriers preventing the use of concept mapping in EC settings, that of children being able to make symbols explicit, include linking phrases, and abstract concepts autonomously.

We do not know yet if the Kit facilitates concept mapping instruction as concept mapping was not introduced in this test. Moreover it was not a goal of this study to show that the ability to verbally add meanings to symbols will solve all the problems surrounding this strategy in the EC classroom. By adding verbalization via voice-input to the knowledge representation process, we are turning the discussion to more fundamental questions such as: what strategies are appropriate to introduce children to proposition making or the understanding of connections? The problems for concept mapping in preschool are beyond the representational disadvantages presented. However thinking, developing and testing prototypes similarly to the Kit described in this paper is a useful way to stimulate productive discussions that lead to the implementation of educationally sound and effective concept mapping tools for this age group.

7 Future Work

The results indicate that the Kit could be adapted to any EC classroom. Recently I have undertaken a follow-up study at a US university-based kindergarten classroom with teachers familiar with the children's needs. Discussion of this study is beyond the scope of this paper, however to view two resulting maps visit http://www.gloriagomez.com/BigCats-Tigers.swf and http://www.gloriagomez.com/BigCats-Leopards.swf. Future work will involve a two-month pilot study in the same US-university setting, working in a multi-disciplinary team, where we will teach children to concept map.

References

Badilla, S. (2004). Experiencia Pedagógica: Mapas Conceptuales en Preescolar. Memorias V Congreso Nacional de Educadores. Programa Nacional de Informatica Educativa MEP-FOD (Preescolar, I y II Ciclos).

Mettler, R. [Illustrator], De Bourgoing, P., & Jeunesse, G. [Creators] (1990). The Egg. London: Moonlight Publishing.

Figueiredo, M., Lopes, A. S., Firmino, R., & De Sousa, S. (2004). "Things We Know about the Cow": Concept Mapping in a Preschool Setting. In Cañas, A. J., Novak, J. D., & González, F.M. (2004). Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping.

FOD - Fundacion Omar Dengo. (2004) Online Forum with Doña Eleonora Badilla-Saxe. Foros Institucionales: V Congreso Nacional de Educadores PRONIE ME-FOD (Preescolar, I y II Ciclos). Costa Rica, August 24, 2004.

Gomez, G. (2005). Young Children's use of a Voice-Input Device to Transform Their Symbolic Maps into Concept Maps. Paper presented at Our Children the Future Conference 2005 (OCTF 4).

Keates, S., & Clarkson, J. (2003). Countering Design Exclusion: An Introduction to Inclusive Design. Springer.

Mancinelli, C., Gentili, M., Priori, & G., Valitutti, G. (2004). Concept Maps in Kindergarten. In: Cañas, A. J., Novak, J. D., & González, F.M. (2004). Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping.

Mérida, R. (2002). Una Nueva Forma de Trabajar en Educación Infantil: Los Mapas Preconceptuales / A New Approach to Preschool Education: Conceptual Maps. Cultura y Educación 14(1), 99-125.

Mérida, R. (2001-2002). Ayudando a Organizar el Pensamiento Infantil: Los Mapas Preconceptuales,. Kikiriki: Cooperacion Educativa 62-63 (Double Issue).

Norman, D. A. (c1998). The Invisible Computer: Why Good Products can Fail, the Personal Computer is so Complex, and Information Appliances are the Solution. Cambridge: MIT Press.

Novak, J. D. (1998). Learning, Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Earlbaum Associates.

Novak, J.D., & D. B. Gowin (1984). Learning How to Learn. New York: Cambridge University Press.

Perez Cabani, M. L., Falgas, M., Nadal, A., & Valenti, M. (1992). Els Mapes Conceptuales: una estrategia d'aprenentatge al parvulari. Revista Guix181.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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APLICACIÓN DE LA TÉCNICA DE ANÁLISIS ESTRUCTURAL DE MAPAS CONCEPTUALES (AEMC) EN UN CONTEXTO DE EDUCACIÓN CTS

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Resumen. Presentamos la aplicación de un método para interpretar mapas conceptuales que combina el Análisis Estructural Educativo (AEE) y la prueba o análisis bidimensional Olmstead-Tukey, la cual denominamos como *Análisis Estructural de Mapas Conceptuales mediante la prueba de asociación de Olmstead-Tukey* (AEMC). La metodología fue aplicada a los mapas de 37 alumnos de bachillerato de la UNAM como parte de una estrategia didáctica llamada *injerto* en forma de *Webquest* con el tema de células madre. El injerto es una estrategia basada en el aprendizaje cooperativo que esta asociada con el enfoque educativo de Ciencia, Tecnología y Sociedad (CTS). Se construyó un mapa experto con 16 conceptos y sus respectivos conectores sobre el tema de células madre con base en la información de la Webquest. El mapa experto se modificó para que al ser suministrado al alumno, éste eligiera los conceptos de una lista y los colocase en el sitio del mapa que considerase correcto. El llenado de mapas por parte del alumno se realizó en dos ocasiones, *antes* de la actividad del injerto y *después* de finalizada. Los mapas obtenidos fueron procesados por medio de la técnica del AEMC. Los resultados muestran que la estrategia del injerto contribuyó a la identificación de conceptos y establecimiento de relaciones con los conceptos de células madre, en particular los asociados a la transformación de la célula. Sin embargo, también muestran que se requiere un reforzamiento posterior a la técnica del injerto, por lo que recomendamos que el injerto se aplique al inicio de la unidad didáctica y no al final, De esta forma el AEMC sería empleado como herramienta diagnóstica y reorientar las actividades de aprendizaje del resto de la unidad didáctica. La evaluación de los injertos se ha enfocado a los valores y actitudes mediante cuestionarios, descuidando el hecho de que los conceptos tecnocientíficos requieren de ser evaluados por otros instrumentos. La aplicación del AEMC es una contribución en este sentido.

1 Introducción

Los mapas conceptuales han sido aplicados en un amplio contexto de situaciones (Cañas *et. al*, 2004) y se han traducido en líneas específicas de investigación en el área educativa. Una de ellas es utilizar los mapas conceptuales como herramienta para explicitar y valorar como un estudiante selecciona y enlaza diferentes conceptos. Ruiz-Primo & Shavelson (1996) describieron un conjunto de factores ha considerar al utilizar los mapas conceptuales con estos fines: a) tipos de conceptos, b) tipos de líneas de conexión, c) frases o explicaciones de conexión, y d) estructura espacial o jerárquica. Por otra parte, las técnicas de construcción de un mapa difieren en el tipo y cantidad de piezas del mapa que se le proporcionan al estudiante o que se le solicita que genere, de tal forma que en algunas investigaciones se contrastan las dos técnicas generales para la obtención de mapas: *"fill-in-map"* (FM) y *"construct-a-map* (CM); los resultados obtenidos sugieren que las dos técnicas (FM y CM) producen mapas cuya interpretación no es equivalente debido a la influencia que ejerce la técnica elegida (consultar Ruiz-Primo et. al, 2001; Ruiz-Primo, 2004; Yin et. al, 2005)

La técnica de FM consiste en suministrar un mapa al alumno, al cual se le han eliminado piezas (conceptos, enlaces, …) por lo que para resolverlo el estudiante tiene que completar los elementos que faltan. Hernández (2005) sugiere que se le proporcione al alumno una lista con los elementos que faltan para evitar problemas de equivalencia semántica entre los elementos propuestos por el estudiante y el mapa experto; la desventaja radica en que se limita la expresión de conocimiento por parte del alumno y por otra parte, es difícil precisar si el estudiante está adivinando cuando coloca el elemento en el mapa.

Para intentar resolver estos planteamientos consideramos que el análisis de los mapas construidos con esta técnica, se debe dirigir a valorar la proposición (concepto-conector-concepto) que explicite el alumno, aunque ésta no coincida con la establecida en el mapa experto o en el lugar indicado por el mismo. De igual manera, si se condensa la información de las proposiciones de los alumnos en un mapa grupal, éste permitiría reconocer repeticiones (por azar o por certidumbre) y contrastar hipótesis de tendencias o patrones (González et. al 2004).

El contexto de esta investigación tiene su origen en la participación de los autores en la *Cátedra México Ciencia, Tecnología y Sociedad + Innovación*, que fue auspiciada por la Organización de los Estados Iberoamericanos y otras instituciones educativas mexicanas como la UNAM, IPN, UAM, entre otras. Con base en la formación recibida, decidimos crear un Seminario llamado *"Injertos: diseño, construcción y validación de material didáctico para fomentar una educación y cultura CTS de la Escuela Nacional Preparatoria, (ENP) UNAM"*. En este seminario, profesores del área de Biología del bachillerato de la ENP, diseñamos y validamos actividades de

aprendizaje (injertos) que permitan ser una alternativa de formación educativa que contribuya a una comprensión de la ciencia y tecnología sin desligarse de sus fines y utilidades sociales, que es lo que denomina Osorio (2002) educación con enfoque ciencia, tecnología y sociedad, (CTS).

El concepto CTS se ubica en un contexto académico, enfocado a los aspectos sociales de la ciencia y la tecnología, y se desarrolla en dos vertientes. El primero se relaciona con los factores sociales asociados al cambio científico y tecnológico, el segundo con las consecuencias sociales y ambientales como producto del desarrollo de la ciencia y tecnología. La influencia del enfoque CTS ha sido tal que en varios países se ha decidido modificar la curricula de diversas instituciones educativas (García et al. 2001; Osorio 2002). Existen diferentes mecanismos para introducir el enfoque CTS en los curricula; Osorio (2002) sugiere que por la complejidad de los sistemas educativos latinoamericanos, los injertos son una opción adecuada. Un injerto es un añadido temático que a partir de una situación real o ficticia, permite que el alumno desarrolle una valoración crítica sobre las consecuencias en la sociedad de la adopción de tecnologías o conocimientos científicos, entre otros aspectos y que está sustentado en un aprendizaje cooperativo. Un referente de los injertos es el presentado por Argos (2001) y Gordillo (2001).

Para validar los injertos nos enfocamos en dos mecanismos; el primero fue el diseño de un cuestionario que permitiera indagar la parte afectiva o de valores del alumno, y la segunda fue la aplicación de un mapa conceptual relacionado con los contenidos tecnocientíficos. Existe evidencia empírica que corrobora el hecho de que el uso de mapas conceptuales favorece el proceso de aprendizaje; Markow & Lonnig (1998) encontraron que alumnos de un curso de laboratorio de química se beneficiaron con la elaboración de premapas y postmapas. Yarden et. al (2004) mencionan que el utilizar mapas conceptuales contribuyó en el aprendizaje de alumnos e instructores para el tema de la estructura del ADN y funciones de ácidos nucleicos. En este trabajo el uso de los mapas conceptuales tiene una doble función: por una parte es un elemento que contribuye al proceso de aprendizaje del tema eje del injerto, pero también es un mecanismo de evaluación y validación.

La utilización de diferentes herramientas teóricas y metodológicas en conjunto con los mapas conceptuales no es algo nuevo, como lo demuestra la investigación de Odom & Kelly (2001) en la que relaciona los mapas conceptuales con los círculos de aprendizaje (*"learning cycle"*). Para este trabajo, como ya mencionamos anteriormente, utilizaremos la técnica FM, en combinación con el *Análisis Estructural Educativo* (AEE) propuesto por Solano (1989) y la *Prueba o Análisis Bidimensional Olmstead-Tukey* (Sokal. & Rohlf, 1985, García de León, 1988).

Solano (1989) señala que el "*Análisis Estructural Educativo* ... es un conjunto de razonamientos, técnicas, y algoritmos ... que permiten plantear y resolver problemas pertenecientes al campo de la educación, a partir de la idea de estructura"; su aplicación es amplia: diseño y evaluación curricular, análisis de contenido, evaluación de material didáctico, entre otras. Los procedimientos de trabajo en el AEE están sustentados en el álgebra lineal y booleana así como la Teoría de Grafos, generando imágenes que son semejantes a los mapas conceptuales en el sentido de reflejar conjuntos de elementos vinculados por diferentes tipos de relaciones. Considerando esta semejanza, utilizamos algunos procedimientos de trabajo del AEE para interpretar los mapas resueltos por los alumnos al participar en el injerto.

El análisis Olmstead-Tukey tiene una utilización práctica en estudios de ecología, ya que permite determinar de manera gráfica cuales especies de un ecosistema son dominantes, constantes, ocasionales y raras (Rodríguez-Villanueva, et. al, 2003), pero que nosotros adaptamos para identificar los conceptos dominantes, constantes, ocasionales y raros en un mapa conceptual (González et. al 2004). El procedimiento para llegar a la elaboración de las gráficas Olmstead-Tukey coincide con los utilizados en el AEE, ya que emplean operaciones con matrices para generar resultados. La combinación de ambas técnicas la denominaremos como *Análisis Estructural de los Mapas Conceptuales mediante la utilización de la prueba de asociación Olmstead-Tukey* (AEMC), y que nos permitirá la transformación de los datos del mapa para su interpretación.

2 Metodología

El injerto consistió en el planteamiento de un problema ficticio asociado con la pertinencia de que en México se creará un Banco de Células Madre para Latinoamérica. A cada alumno se le asignó la representación de un personaje (científico, diputado, representante religioso, medio de comunicación, etc.), de tal forma que en el grupo

estuviesen opiniones a favor, en contra e indecisos para la creación del banco de células madre. La actividad tuvo una duración de cinco sesiones de 50 minutos cada una, siendo algunas consecutivas. En las sesiones los alumnos se agruparon por sectores afines a sus posturas, en dónde discutían y se preparaban para el debate y su recomendación sobre la creación del banco de células madre. De manera programada se interrumpían sus sesiones para entrevistas, en las que todos escuchaban al entrevistador y el entrevistado, y así oír otras opiniones. Al final, concluyó con una reflexión individual y grupal sobre el planteamiento original: la creación del banco de células madre.

La participación de los alumnos en el injerto requería que estuviesen informados acerca de la postura del personaje que interpretaban, del tema de células madre, el orden en que participarían y otros detalles de organización. Considerando las habilidades de los alumnos para consultar Internet, se decidió emplear una estrategia de aprendizaje colaborativo llamada WebQuest. Esta estrategia de aprendizaje fue propuesta por Bernie Dodge y Tom March (Dodge, 1997, March, 1997) y que consiste en la creación de una página web con una estructura que es complementaria y coherente con la estrategia del injerto. La página elaborada y en donde se ubica el injerto tiene como dirección http://mx/geocities.com/enpbiologia/

En la WebQuest hay una sección con direcciones electrónicas que permitía al alumno fundamentar el conocimiento de su personaje, pero también su conocimiento sobre las células madre. De manera específica se les indico a los alumnos que participaban en el injerto, que tenían que consultar las siguientes direcciones electrónicas:

- http://www.ecojoven.com/uno/05/celulasm.html
- http://www.biotech.bioetica.org/clase2-17.htm
- http://www.bionetonline.org/castellano/Content/sc_cont1.htm

Estas direcciones fueron seleccionadas por contener información tecnocientífica especializada en células madre, adecuada al grado educativo de los alumnos. Con base en esta información, los autores elaboramos un "mapa conceptual experto" con 16 conceptos y sus respectivos conectores (figura 1). Posteriormente, quitamos los conceptos del mapa y los colocamos en una lista ordenada alfabéticamente. Este mapa fue el que se le suministró al alumno para que completara los conceptos, al menos en dos ocasiones; la primera fue al inicio, cuando de manera previa había consultado la información pero no la había discutido con sus compañeros. Este mapa lo denominaremos con la palabra "*antes*". La segunda ocasión de aplicación, fue previo a la actividad de cierre del injerto, cuando ya había transcurrido el debate. A este mapa lo denominaremos "*después*".

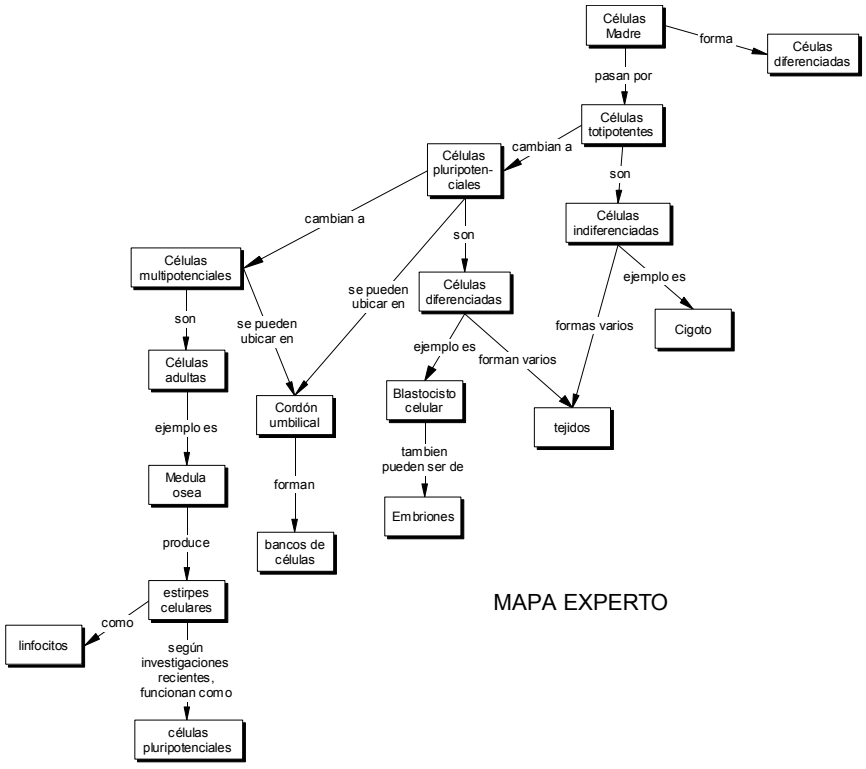


Figura 1. Mapa experto elaborado por los autores del trabajo.

Se aplicó la prueba de χ^2 (ji cuadrada) entre las relaciones correctas de los conceptos dominantes para estimar si hay un cambio en las proporciones *antes* y *después* de la actividad del injerto (Sokal & Rohlf, 1985).

La aplicación del injerto fue del 14 al 26 de marzo de 2006 en cinco sesiones de 50 minutos. Es importante añadir que los alumnos sabían que es un mapa conceptual y cómo construirlo. Basándose en las características de las lecturas a partir de las cuales se elaboró el mapa experto, hay dos conceptos que se repiten (células diferenciadas y células pluripotenciales). En la lista de palabras que se les entregó tenían la advertencia de que dos conceptos se repetían, cada uno, dos veces en el mapa. Por otra parte en ninguna de las aplicaciones se les aviso a los alumnos que tendrían que resolver un mapa conceptual.

3 Resultados

Los alumnos que participaron en el injerto CTS, corresponden a dos grupos de la asignatura Temas Selectos de Biología que se fusionaron para tal fin, siendo 37 alumnos en total; la proporción de sexos fue de 57% mujeres y 43% hombres con edades de 17 a 19 años principalmente.

Cada mapa elaborado por alumnos se transformó en una matriz de asociación. Solano (1989) indica que en el AEE las matrices se pueden analizar los renglones o las columnas. Si se utilizan los renglones, se analiza como un concepto A se relaciona con B, C, D... Si se emplean las columnas se analiza como los conceptos E, F, G ... se relacionan con el concepto H. Nosotros utilizamos los renglones de la matriz.

Con las matrices se efectuó una sumatoria para obtener dos matrices grupales (*antes* y *después*) procedimiento similar al que se propone en el AEE. Tomando en cuenta estas matrices se calcularon los porcentajes de las frecuencias de relación de un concepto con respecto a los otros, y el total de relaciones que establece cada concepto, se aplicó la prueba de asociación Olmstead-Tukey. En la tabla 1 se muestra la matriz grupal *después* con los dos parámetros anteriormente citados, además de su mediana respectiva. La matriz general *antes* es similar, pero por limitaciones de espacio no es presentada. Utilizando las medianas de las frecuencias de relación y del total de relaciones se clasificaron los conceptos en dominantes, ocasionales, constantes y raros (tabla 2 y figura 2).

DESPUES CORRECTO	banco de células	blastocisto celular	células adultas	células diferenciadas	células indiferenciadas	células madre	células multipotentes	células pluripotentes	células totipotentes	cigoto	cordón umbilical	embriones	estirpes celulares	linfocitos	médula ósea	tejidos	Total de relaciones	frecuencia de relación	% frec de relación
banco de células																	0	0	0
blastocisto celular								1	1							2	4	3	19
células adultas				4					4		1		1		3	2	15	6	38
células diferenciadas		1	5				3	4			4	1			3	6	27	8	50
células indiferenciadas			1	2					4	3			2			8	20	6	38
células madre	10			2	1				15	4	2	4	3			3	44	9	56
células multipotentes			3	14				4			7	1			9	2	40	7	44
células pluripotentes		2		17			18		2		7	1			2	3	52	8	50
células totipotentes			1		7	4		13		3	1					2	31	7	44
cigoto		6			1							4	2			2	15	5	31
cordón umbilical	4			2													6	2	13
embriones				1													1	1	6.3
estirpes celulares														1		1	2	2	13
linfocitos																	0	0	0
médula ósea							1	1					1	14		1	18	5	31
tejidos															1		1	1	6.3
mediana																	16		32

Tabla 1 Matriz grupal *después* de la aplicación del injerto de células madre. Las casillas sombreadas corresponden a las relaciones entre conceptos del mapa conceptual experto.

Otro dato representado en las matrices grupales corresponde a información del mapa conceptual experto; las casillas sombreadas indican cuales son las relaciones que se establecen entre los conceptos a partir del mapa experto (tabla 1). Con base en las matrices grupales se elaboraron mapas *antes* y *después* de la aplicación, considerando las relaciones totales entre los conceptos de dichas casillas. Una relación correcta se definió en dos sentidos: a) debería coincidir con la casilla sombreada, b) La relación entre los dos conceptos y su conector (proposición), era válida desde la perspectiva del contenido de las lecturas, independientemente de que no coincidiera con una casilla

sombreada. La frecuencia de relaciones correctas se transformó a porcentajes partiendo de que el valor máximo para cada casilla sombreada es de 37, que corresponde al total de alumnos que construyeron su mapa.

Antes y Después de la aplicación			
Conceptos Dominantes	**Conceptos Ocasionales**	**Conceptos Constantes**	**Conceptos Raros**
Células diferenciadas	Médula ósea	Células adultas	Blastocisto celular
Células indiferenciadas			Cordón umbilical
Células madre			Embriones
Células multipotenciales			Estirpes celulares
Células pluripotenciales			Linfocitos
Células totipotenciales			Tejidos (solo aparece en antes)
Antes de la aplicación			**Después de la aplicación**
Cigoto			*Cigoto*

Tabla 2: Clasificación de los conceptos del injerto de células madre antes y después de su aplicación, utilizando la prueba de asociación Olmstead-Tukey

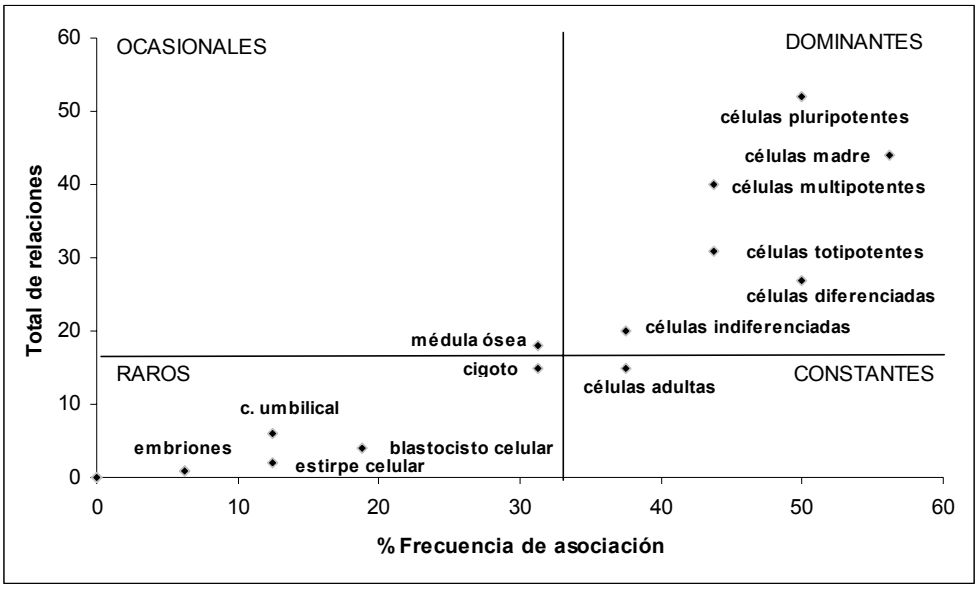


Figura 2. Clasificación de los conceptos mediante la prueba de asociación Olmstead-Tukey que corresponde a la aplicación posterior (después) del injerto de células madre.

En la tabla 2 se presenta la clasificación de los conceptos con base en la prueba de asociación Olmstead-Tukey. Al hacer un análisis comparativo de las matrices grupales (*antes* y *después*) considerando las relaciones totales y frecuencias de asociación, se obtuvo que con excepción de el concepto cigoto (que cambio de dominante a raro) y el concepto tejidos (solo aparece en la matriz *antes*), el resto de los conceptos no presento modificación en su categorías inicial (*antes*) y final (*después*). En la figura 2 se tiene la representación gráfica. Con respecto a las medianas como criterio de clasificación de los conceptos, se observa que para la primera aplicación (*antes*) son 22% para el porcentaje de frecuencia de asociación y 7.5 para el total de relaciones. Con respecto a la aplicación posterior (*después*) el valor de mediana es 32% y 16 de frecuencia total de relaciones.

Con base en las matrices grupales de los mapas conceptuales *antes* y *después*, se obtienen porcentajes de relación de un concepto con respecto a otro. Al considerar aquellos porcentajes de relación que están vinculados al mapa experto, se generaron dos mapas del grupo que se muestra en la figura 3. Al realizar comparaciones entre los mapas se observa: a) un incremento en la frecuencia de conceptos utilizados por los alumnos de 12 a 17 de un total de 19 (63% a 89%); b) con respecto al tipo de proposiciones destacaríamos que 14 presentan incremento desde 3 hasta 38 puntos porcentuales; 2 proposiciones se mantienen constantes (8% y 19%); 2 proposiciones no fueron utilizadas en ambos mapas; 4 presentaron incrementos a partir de cero.

Las proposiciones con un mayor incremento en puntos porcentuales (18 a 38) están constituidas por los conceptos clasificados en la prueba de Olmstead-Tukey como dominantes. Al aplicar una prueba de ji cuadrada a las frecuencias de relación de los conceptos dominantes en los mapas *antes* y *después*, no se encuentran diferencias significativas (χ^2= 8.4; gl=12, p=. 0.75, no significativa).

En la tabla 3 se muestran las proposiciones con un mayor incremento en puntos porcentuales y que están asociados al primer y segundo nivel jerárquico del mapa experto. Este primer y segundo nivel jerárquico están interconectados con una secuencia de transformación de la célula, aspecto central en el tema de células madre que se analizó con la estrategia del injerto.

En el caso de las proposiciones correctas que no corresponden a la señalada en el mapa experto se cuantificaron 48 y 53 proposiciones en las matrices grupales *antes* y *después*. La mayoría de estas proposiciones se caracterizan por ser mencionadas de manera individual y no grupal, por lo que únicamente se destacan tres por su incremento al comparar las matrices grupales *antes* y *después* (tabla 4).

De acuerdo al AEMC los conceptos banco de células, cigoto, embriones, linfocitos y tejidos, no presentan casillas sombreadas en los renglones de las matrices, ya que son conceptos terminales en el mapa conceptual experto y no deberían aparecer en la gráfica de Olmstead-Tukey, como es el caso del concepto de banco de células. Pero el resto de los conceptos si es cuantificado en las matrices *antes* y *después*, y en la gráfica Olmstead Tukey.

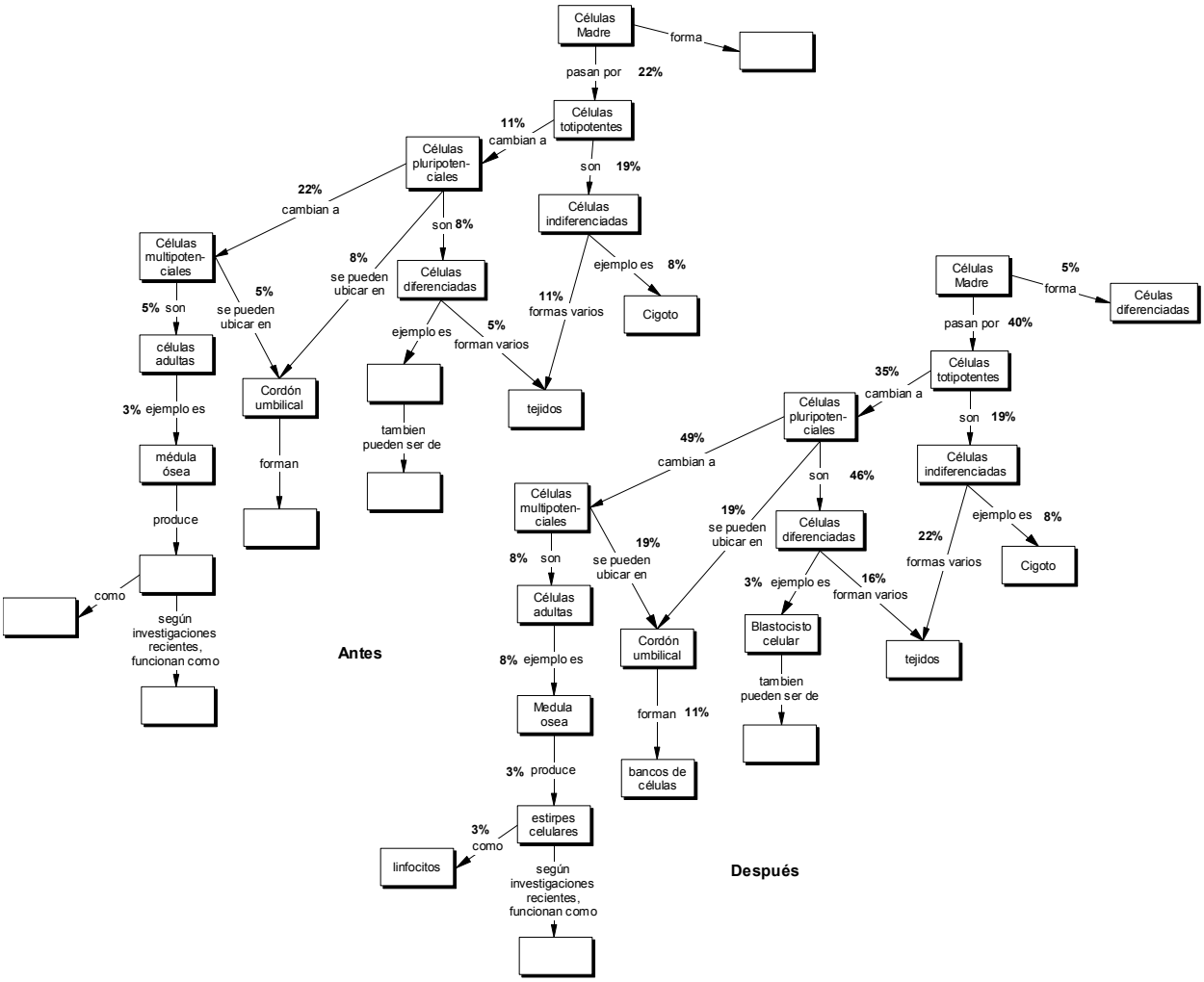


Figura 3. Representación de los mapas grupales *antes* y *después*, tomando en cuenta el total de relación de un concepto con respecto a otro en porcentaje.

Proposición (concepto-*conector*-concepto)	Incremento en puntos porcentuales
[células madre -*pasan por*- células totipotentes]	18
[células totipotentes-*cambian a*-células pluripotenciales	24
[células pluripotenciales -*cambian a*- células multipotenciales]	27
[células pluripotenciales-*son*-células diferenciadas]	38

Tabla 3. Proposiciones que presentaron los máximos incrementos porcentuales al comparar el mapa grupal *antes* con el mapa *después*

Proposición (concepto-*conector / conector*-concepto)	Incremento en puntos porcentuales
[células multpotenciales -*son*- células diferenciadas]	16
[médula ósea-*forman / produce*- linfocitos	14
[células madre -*forman*- bancos de células]	8

Tabla 4. Proposiciones que presentaron los máximos incrementos porcentuales al comparar el mapa grupal *antes* con el mapa *después*

4 Discusión y conclusiones

De acuerdo a la prueba de asociación Olmstead-Tukey, los conceptos dominantes son casi los mismos antes y después de la aplicación de la estrategia didáctica del injerto. Esto se puede interpretar como evidencia de que el injerto no distorsiona la identificación de los elementos importantes del tema. Por el contrario, aparentemente contribuye a que un mayor número de alumnos los identifiquen al final de la actividad, como lo sugiere el incremento de los valores de las medianas en la prueba Olmstead-Tukey.

En el caso del concepto cigoto que es el único que se modificó después de la aplicación del injerto (dominante a raro), indica como esta estrategia favoreció el que de manera colectiva lo ubicaran en una categoría más adecuada al contexto específico del tema que se analizó. El concepto cigoto en un alumno de bachillerato es importante en su lenguaje académico, ya que es mencionado y utilizado como objeto de aprendizaje en diferentes asignaturas, pero en una investigación especializada como es el tema de células madre, es un antecedente y deja de ser concepto incluyente. Una línea de investigación quizá sería el incluir algunos conceptos dominantes o raros en el esqueleto del mapa que se le entrega al alumno. La hipótesis sería establecer si un concepto dominante o raro puede orientar la ubicación del resto de los conceptos en el mapa.

Por otra parte, el incremento del porcentaje de proposiciones establecidos por los alumnos después de la aplicación del injerto, sugiere algún beneficio en su aprendizaje, aunque no de manera clara ya que la prueba estadística de ji cuadrada no fue significativa para los conceptos dominantes. Esto implicaría que el profesor debiera orientar su labor al reforzamiento de este contenido. En particular los conceptos que se ubican en el primer y segundo nivel jerárquico del mapa experto están conectados con la idea de cambio o transformación de la célula, y es en estos niveles dónde ocurrieron los incrementos posteriores a la aplicación del injerto.

El gran número de proposiciones correctas establecidas por el alumno fuera del mapa experto sugiere que las frases de conexión deben de ser analizadas en su versatilidad para asociar conceptos, ya que palabras como *son, forman y producen* son susceptibles de ser empleadas en contextos muy amplios. Si se corrige este detalle quizá sea útil el analizar estas proposiciones que el alumno genera fuera del mapa experto para reorientar las actividades de aprendizaje o del mapa experto.

El injerto fue aplicado al final de la unidad didáctica considerando que los temas analizados previamente favorecerían su participación en el injerto. Los resultados de los mapas conceptuales sugieren que quizá sea más útil el emplear el injerto al inicio, ya que el AEMC se utilizaría como diagnóstico sobre los conceptos y proposiciones que presenten un manejo deficiente en el grupo y de esta forma reorientar el diseño de las actividades de aprendizaje en el resto de la unidad.

A manera de conclusión señalaríamos que dentro del AEMC la prueba de Olmstead-Tukey indica cuales son los conceptos dominantes que utilizan los alumnos, y el AEE describe el cómo los conceptos dominantes establecen proposiciones válidas, las cuales pueden estar ubicadas en un lugar jerárquico similar o distinto del mapa experto.

Los injertos son una estrategia para fomentar valores, y que parte de un manejo mínimo de conceptos tecnocientíficos (García et al. 2001; Osorio 2002); la evaluación de los injertos se ha enfocado a los valores y

actitudes mediante cuestionarios, descuidando el hecho de que los conceptos científicos requieren de ser evaluados por otros instrumentos. La aplicación del AEMC es una contribución en este sentido.

5 Agradecimientos

A la Dirección General de Asuntos del Personal Académico (DGAPA), por el apoyo recibido a través del programa Iniciativa para Fortalecer la Carrera Académica del Bachillerato de la UNAM (INFOCAB), con el proyecto INFOCAB SB-000136 *"Injertos: Diseño, construcción y validación de material didáctico para fomentar una educación y cultura CTS de la Escuela Nacional Preparatoria (ENP) en la UNAM.*

Referencias

Argos, Grupo. (2001). *Ciencia, Tecnología y Sociedad, materiales para la educación secundaria.* Asturias: Grupo Ed. Norte.

Cañas, A. J., Novak, J. D., y González Fermín, Eds. (2004). *Concept Maps: Theory, Methodology, Technology. Proc. of the 1st Int. Conf. on Concept Mapping.* Vol. 1. Pamplona: Universidad Pública de Navarra.

Dodge, B. (1995). Some thoughts about WebQuests, In <http://edweb.sdsu.edu/courses/edtec596/about_webquests.html>. [Consulta 20/04/2006].

García de León, L. A. (1988). *Generalidades del análisis de cúmulos del análisis de componentes principales.* México: Instituto de Geografía, UNAM.

García Palacios, E. M., González Galbarte, J. C., López Cerezo, J. A., Lujan, J. L., Gordillo Mariano, M., Osorio, C. & Valdez, C. (2001). *Ciencia, tecnología y sociedad: una aproximación conceptual.* Madrid.: Organización de Estados Iberoamericanos.

González Yoval, P., Hermosillo Marina, S., Chinchilla Sandoval, E., García del Valle, L & Verduzco Martínez, C. (2004). Valoración cuantitativa para evaluar mapas conceptuales. In Cañas, A.J., Novak, J. D., y González Fermín (eds). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping.* Vol. 1. (pp. 289- 294) Pamplona: Universidad Pública de Navarra.

Gordillo Martín, Mariano. (2001). *AIDS-2001: la vacuna contra el SIDA. Simulación educativa de un caso CTS sobre la salud.* Madrid: Organización de Estados Iberoamericanos.

Hernández Forte, V. (2005). *Mapas conceptuales. La gestión del conocimiento en la didáctica.* México: Alfaomega

Markow, P. G. & Lonnig, R. A. (1998). Usefulness of Concept Maps in College Chemistry Laboratories: Students' Perceptions and Effects on Achievement. *Journal of Research in Science Teaching, 35(9),* 1015-1029.

March, T. (1997). The WebQuest design process. In. <http://www.ozline.com/webquests/design.html>, Consulta 20/04/2006.

Odom, P. & Kelly, V. (2001). Integrating concept mapping and the learning cycle to teach diffusion and osmosis concepts to high school biology students. *Science Education 85 (6),* 615-s635

Osorio, C. (2002). La educación científica y tecnológica desde el enfoque de ciencia, tecnología y sociedad. Aproximaciones y experiencias para la educación secundaria. *Revista Iberoamericana de Educación, (28),*61-82.

Rodríguez-Villanueva, V. Martínez-Lara, R. & Macías Zamora, V. (2003). Polychaete community structure of the northwestern coast of Mexico: patterns of abundance and distribution. *Hydrobiologia 496(1-3):*385-399

Ruiz-Primo, M. A. (2004). Examining concept maps as an assement tool. In Cañas, A.J., Novak, J. D., y González Fermín (eds). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping. Vol*. 1. (pp. 555-562) Pamplona: Universidad Pública de Navarra.

Ruiz-Primo, M. A., Schultz, S E., Li, M. & Shavelson, R.J. (2001). Comparison of the Reliability and Validity of Scores from Two Concept-Mapping Techniques. *Journal of Research in Science Teaching, 38(2),* 260-268.

Ruiz-Primo, M. A: & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33(6),* 569-600.

Sokal, R. & Rohlf, F. (1985). *Biometry.* San Francisco: W. H. Freeman and Company.

Solano Flores, G. (1989). *Principios de análisis estructural educativo. Metodologías sy técnicas para la educación:* México: 2da edición, Trillas:

Yarden, H, Marbach-Ad, G. & Gershoni, J. M. (2004). Using the concept map technique in teaching introductory cell biology to College Freshmen. *Bioscience, 30 (1,)* 3-13.

Yin, Y., Vanides, J., Ruiz-Primo, M. A., Ayala, C. C. & Shavelson, R. J. (2005). Comparison of Two Concept-Mapping Techniques: Implications for Scoring, Interpretation, and Use. *J. of Res. in Science Teaching, 42(8),* 705-711.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

APLICACIÓN DE LOS MAPAS CONCEPTUALES (MMCC) Y DE LA V DE GOWIN EN LA ELABORACIÓN DE MÓDULOS INSTRUCCIONALES EN ALUMNOS DE MAGISTERIO

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Abstract. Se describe en esta experiencia la elaboración de módulos instruccionales en la asignatura de Conocimiento del Medio natural, social y cultural en alumnos de 2º Curso de Magisterio a través de las herramientas heurísticas: MMCC y V de Gowin. Se constata, a través de un análisis cualitativo, que nuestros alumnos, utilizando estas herramientas, logran mejores aprendizajes, más significativos y duraderos y adquieren competencias profesionales a través del trabajo autónomo y colaborativo. Además el análisis de las respuestas del cuestionario de valoración final y de las actas periódicas realizadas por los alumnos ponen de manifiesto el alto grado de satisfacción de los mismos. La herramienta informática CmapTools ha permitido optimizar los distintos procesos.

1 Introducción

En el marco de la asignatura de Conocimiento del Medio natural, social y cultural de la Diplomatura de Maestro (especialidades de E. Infantil, Musical y Lengua Extranjera), los alumnos tienen que elaborar un Módulo Instruccional sobre el parque de la Taconera de Pamplona con utilización de las herramientas heurísticas de los MMCC y la V de Gowin, a través de una metodología basada en la actividad grupal y el trabajo autónomo. El Módulo Instruccional recoge el planteamiento teórico del trabajo, búsqueda y organización de la información, elaboración de materiales curriculares, presentación en un CD y exposición del mismo. Todo ello a partir del programa informático CmapTools que permite no sólo la asociación de otros elementos de conocimiento como documentos escritos, imágenes, videos o páginas Webs, sino la conexión a través del servidor público de la Universidad Pública de Navarra con los componentes del grupo, con los profesores y con centros educativos de la comunidad foral de Navarra. La introducción del programa informático CmapTools en algunas escuelas de Navarra nos está permitiendo la extensión del trabajo con MMCC a los niveles de Educación Infantil y Primaria y la relación con maestros que se han involucrado en el uso de las mismas

Este artículo presenta la aplicabilidad de estas herramientas en la elaboración de materiales curriculares sobre el área de Conocimiento del Medio Natural Social y Cultural de alumnos de 2º de Magisterio de Educación Infantil y Primaria en la Universidad Pública de Navarra y la constatación del cambio conceptual y metodológico reflejado en el documento informático elaborado por ellos, en las actas y valoraciones entregadas y en el cuestionario realizado. Además, la metodología implementada facilitará a los alumnos abordar con éxito los desafíos que plantea el cambio de paradigma educativo implícito en la llamada Sociedad del Conocimiento y de la Información y el recién creado Espacio Europeo de la Educación Superior.

2 Las herramientas heurísticas: Mapas conceptuales y "V de Gowin" y la herramienta informática CmapTools

Los MMCC (Novak y Gowin 1988) son representaciones gráficas de varios conceptos y sus interrelaciones. A través del mapa conceptual los alumnos organizan y jerarquizan sus conceptos representándolos de forma visual. Son instrumentos que posibilitan un aprendizaje significativo.
Los MMCC nos ayudan a identificar, comprender y organizar los conceptos que planeamos enseñar (González y Novak,1996). Permiten también integrar conocimientos de varias disciplinas relacionadas con el área de Conocimiento del Medio (San Martin, Albisu, González, 2004) y adaptar los contenidos científicos al aula. Nos ayudan a especificar las relaciones (proposiciones) necesarias para la comprensión.

La V de Gowin es una herramienta heurística que se puede utilizar para resolver un problema, para entender un procedimiento o para elaborar un diseño instruccional. La elaboración de la parte izquierda de la V resulta eficaz para fundamentar el proceso de enseñanza aprendizaje. Filosofías, teorías, principios y conceptos guían la planificación correcta de esos procesos de enseñanza aprendizaje, que aparecen recogidos en las actividades de presentación, elaboración y resumen y que constituyen los acontecimiento u objetos. La V permite elaborar una base teórica para fundamentar un diseño instruccional. Tanto la V como los MMCC permitirán a nuestros alumnos hacer

operativos los principios teóricos más relevantes del modelo cognitivo constructivista especialmente el aprendizaje significativo y la construcción de conocimiento.

El programa informático CmapTools (Cañas et al., 2004) creado en el prestigioso Institute for Human and Machine Cognition (IHMC) y con un servidor público en la Universidad Pública de Navarra, permite construir, compartir y criticar conocimientos basados en MMCC. Mediante un editor de uso sencillo ,el usuario construye su mapa conceptual y relaciona los medios (vídeo, imágenes, sonidos, mapas, etc.) y sus iconos con los nodos (conceptos). La arquitectura distribuida del sistema permite que los diversos medios y mapas se almacenen en diferentes servidores en una red, y que se pueda acceder desde cualquier nodo en la red. Aprovechando la extensión y omnipresencia de Internet, se puede entonces construir sistemas multimedia accesibles desde cualquier lugar del mundo (González y Cañas, 2003). Desde el punto de vista pedagógico, la construcción de proyectos por parte de los estudiantes usando esta herramienta resuelve un problema común provocado por el fácil acceso a Internet: son tantos los recursos disponibles sobre cualquier tema que para el estudiante es sumamente sencillo copiar y pegar imágenes, texto etc. en su propio documento, sin verdaderamente haberle dedicado tiempo a comprender el tema. Sin embargo si el estudiante debe organizar los recursos mediante MMCC, es sumamente difícil que construya un mapa correcto si no tiene un buen dominio del tema. Las herramientas son sumamente flexibles, y entre sus usuarios se encuentran niños de educación primaria hasta científicos de la NASA.

3 Diseño de la experiencia

3.1 Objetivos

1. Elaboración de un Módulo Instruccional a partir de MMCC y la V de Gowin, presentación en formato CD y exposición oral en clase.
2. Adquisición de competencias profesionales conseguidas a través del trabajo colaborativo y autónomo, utilizando las herramientas heurísticas antes mencionadas.

3.2 Descripción de la experiencia.

3.2.1 Presentación/ sensibilización.

Se realiza en gran grupo. Se comunican objetivos y temática a trabajar. Se propone la realización de un Módulo Instruccional sobre el parque de la Taconera de Pamplona utilizando la V de Gowin, MMCC y el programa informático CmapTools. (Ver Figura 1). Se elige el parque de la Taconera porque se trata de un parque accesible a los alumnos, situado en las proximidades del centro de la ciudad, que integra las características de un entorno natural, social y cultural y muy poco rentabilizado desde el punto de vista didáctico y pedagógico. Este parque se puede considerar como un ecosistema urbano que permite, no sólo la formación de hábitos de trabajo científico, como observación de los distintos elementos del parque, relación de esos elementos con el medio natural, formulación de cuestiones, sino también el desarrollo de una serie de conductas y actitudes positivas que les lleven a cuidar y respetar todos los componentes del parque. (Albisu, San Martín, González, 2003).

El proyecto se centra básicamente en desarrollar unos conceptos científicos clave sobre animales plantas y evolución histórica del Parque de la Taconera para ser trabajados después con alumnos de Infantil y Primaria a partir de unas actividades de presentación, elaboración y resumen. Las actividades se pueden combinar con otras áreas como la lectura, la escritura, las matemáticas, la música y los idiomas. (LEAP, Learning about Ecology Animals and Plants, 1995). La transposición didáctica se realiza a partir de la clarificación conceptual conseguida con la elaboración de MMCC. (San Martín, Albisu y González 2004).

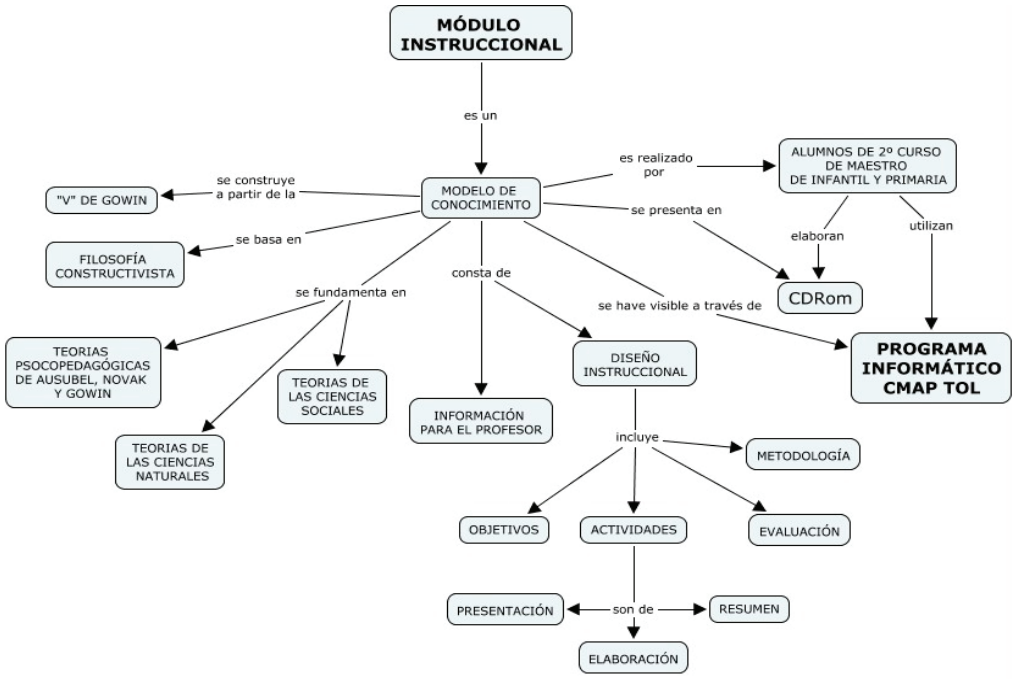


Figura 1. Mapa conceptual que presenta el diseño básico del módulo instruccional que realizan los alumnos

3.2.2 Entrega de material y bibliografía

Resolución de dudas sobre el trabajo planteado y presentación de las herramientas de MMCC, V de Gowin y programa informático CmapTools. En esta sesión se constituyen los grupos de trabajo y se nombran dos responsable de grupo. Uno que se hará cargo del material y tendrá que elaborar actas quincenales y otro que recibe y trasmite la información sobre el programa informático CmapTools proporcionada en tutorías. En las actas se recogen no sólo las actividades que realizan sino también las dificultades y acuerdos a los que ha llegado el grupo y serán un elemento de valoración que se tendrá en cuenta en la evaluación final.

3.2.3 Visita al parque

Visita al parque, acompañados por los profesores, para comprobar "in situ" las posibilidades que ofrece el mismo: animales, plantas y evolución histórica y las zonas de trabajo que le ha correspondido a cada uno según el tema elegido.

3.2.4 Elaboración del trabajo en clase bajo la supervisión de los profesores

- Reflexión y planteamiento teórico del trabajo

Se realiza a partir de la V heurística de Gowin. Se pretende que la V constituya el eje conductor del desarrollo del trabajo, guiándolo en todo momento. Cualquier elemento del módulo instruccional debe estar impregnado por una cosmovisión y guiado por las teorías y principios seleccionados. Las primeras dificultades se presentan en esta parte del trabajo y surgen en el grupo discusiones, debates y planteamientos de problemas que les llevan a tomar acuerdos a consensuar y compartir significados. Los MMCC que deberán realizar en esta parte de la V sobre las teorías psicopedagógicas de Ausubel, Novak y Gowin y sobre las teorías de las ciencias referentes: Biología, Geografía e Historia se muestran muy útiles en esta parte del proceso porque les ayudan a clarificar sus

conocimientos sobre estos temas y les sirven de entrenamiento para su aplicación en los demás elementos de la V Las actas quincenales recogidas en clase ponen de manifiesto los problemas citados anteriormente.

"Hemos tenido algún problema en el planteamiento de la cosmovisión que nos ha ocupado una buena parte del tiempo, pero finalmente dialogando, hemos llegado a un acuerdo"

"Hemos tenido diferentes visiones sobre la cosmovisión y la filosofía y hemos debatido un poco este tema".

"Destacamos que nos ha resultado difícil llegar a una conclusión sobre la cosmovisión"

- Búsqueda y organización del conocimiento.

Para la búsqueda de información consultan las fuentes bibliográficas referenciadas por los profesores. Indagan en la biblioteca de la Universidad y acuden al Archivo Municipal y al Servicio de parques y jardines del Ayuntamiento de Pamplona. La autonomía de los estudiantes se demuestra verdaderamente en esta parte del trabajo y surge una diferenciación de los grupos en relación con las distintas iniciativas de sus componentes.

Otra búsqueda de la información la realizan en el parque de la Taconera. Son frecuentes las visitas realizadas por los miembros del grupo, bien para observar los árboles, arbustos y flores en las distintas estaciones del año: invierno, primavera y verano fundamentalmente, bien para observar los diferentes animales que se encuentran en los fosos de las antiguas murallas de Pamplona o bien para recoger información de los diferentes monumentos que a lo largo del tiempo se han ido instalando en este parque. Previo a la salida realizan fichas de observación en donde irán anotando las características de animales, plantas y de los diferentes monumentos instalados en el parque. Además recogen la información a través de fotografías, vídeos y entrevistas a los cuidadores de animales. Se trata de registros que ya han sido previstos en la elaboración de la V. Y que serán incluidos en el módulo instruccional a través del programa informático CmapTools.

En las entrevistas realizadas a partir de cuestionarios diseñados por los alumnos se recoge todo el conocimiento tácito de cuidadores y jardineros, conocimiento que no aparece en los libros y que nuestros alumnos lo organizan a partir de MMCC. (Figura 2)

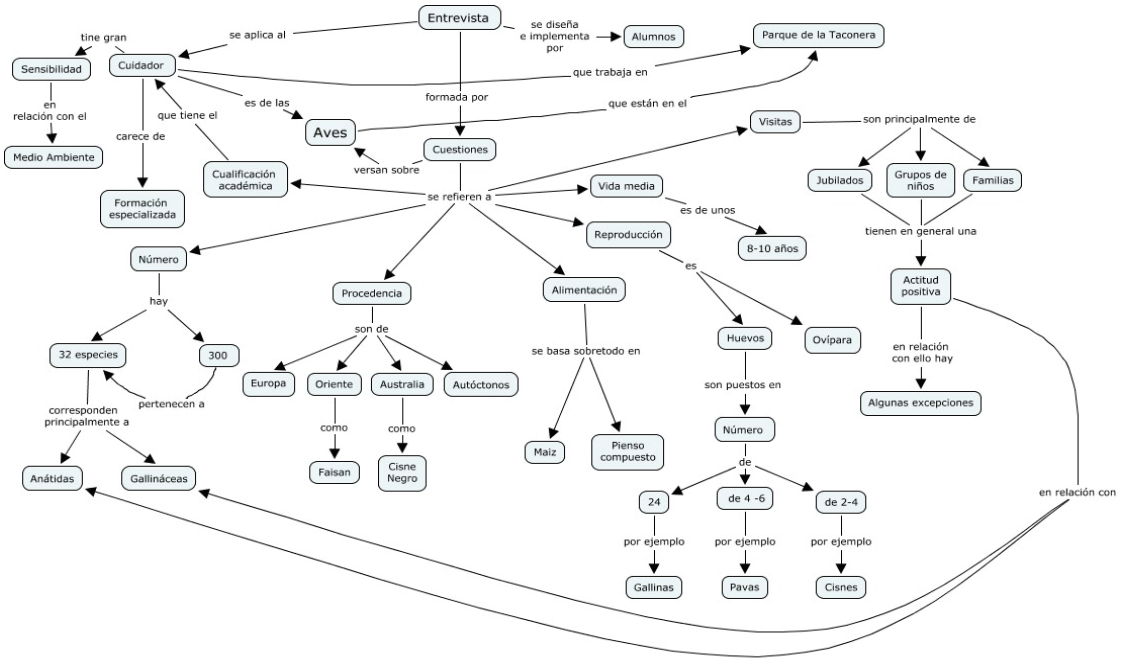


Figura 2. Mapa conceptual de una de las entrevistas realizadas por alumnos con el cuidador de la Taconera, con las principales respuestas

- Elaboración de un diseño instruccional sobre animales, plantas o evolución histórica del parque de la Taconera y presentación en un Cdrom realizado con el programa informático CmapTools.

Esta fase supone la adaptación de los conceptos científicos que sobre animales, plantas y evolución histórica han seleccionado nuestros alumnos para trabajar en el aula con niños de E. Infantil o E. Primaria. La adaptación la realizan siguiendo las orientaciones científicas, didácticas y pedagógicas de los profesores.

Para la elaboración del Módulo Instruccional toman como punto de partida el Diseño Curricular Base de Navarra y elaboran los objetivos didácticos, las actividades y la evaluación. Siguiendo la filosofía constructivista las actividades propuestas deberán ser de tres tipos: presentación, elaboración y de resumen o evaluación. Las actividades de presentación sirven para averiguar lo que los alumnos ya saben. Se realizan a partir de la discusión, la redacción o el dibujo. Las ideas erróneas surgen muchas veces durante estas actividades de presentación. Las actividades de elaboración irán orientadas a cuestionar las ideas previas de los alumnos y a ayudarles a desarrollar conceptos científicos más precisos y complejos. Finalmente las actividades de resumen o evaluación les servirán para contrastar los nuevos conocimientos con sus ideas previas. (Ver Figura 3)

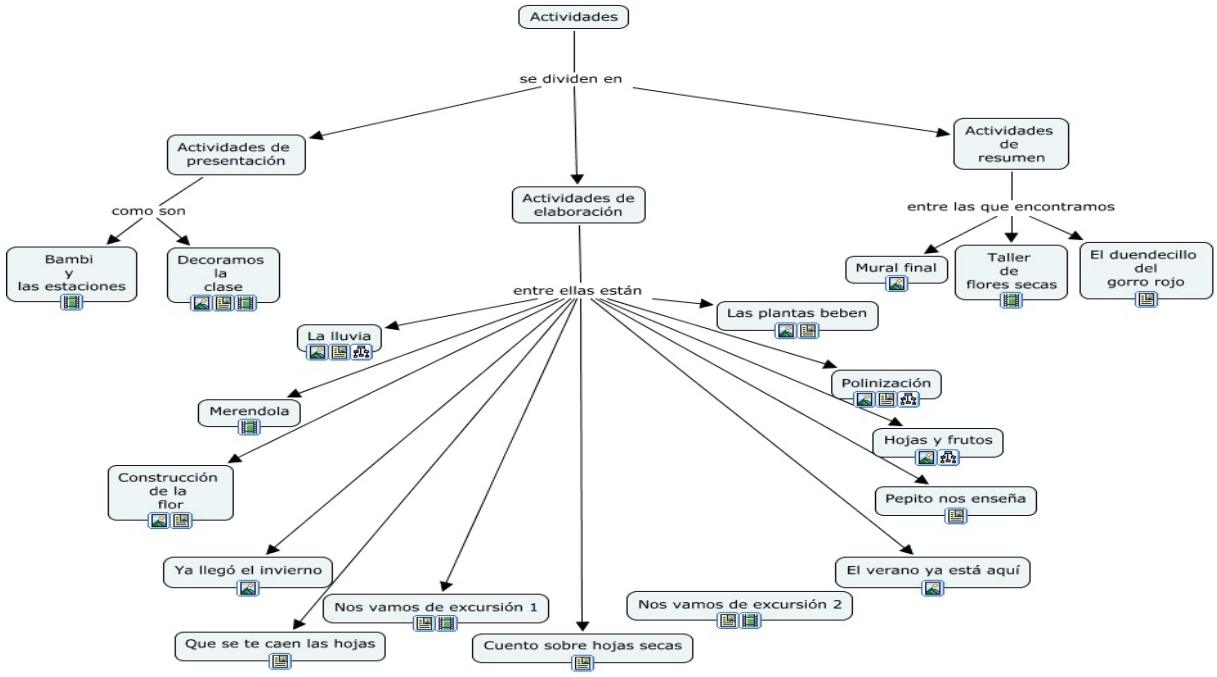


Figura 3. Mapa conceptual que recoge todas las actividades y materiales curriculares elaborados por un grupo de alumnos

Como puede observarse en la figura 3, el trabajo implica la elaboración de materiales curriculares para el desarrollo de las actividades: Fotografías, diapositivas, vídeos cuentos, dibujos, música, viñetas, redacciones y MMCC, aparecen relacionados en el mapa con su actividad correspondiente. En este mapa los iconos que aparecen enlazados a los conceptos se corresponden con los materiales curriculares elaborados por los alumnos.

Todo este trabajo quedará reflejado en un mapa conceptual general recogiendo todos los apartados que integran el Módulo y que deberán presentarlo en formato CD. Las dificultades y problemas que se plantean para introducir toda la información en el programa informático CmapTools se resuelven en horario de tutorías a través de los responsables informáticos.

3.2.5 Exposición de los trabajos

Utilizando las nuevas tecnologías TIC, los alumnos exponen en quince minutos las dificultades encontradas, las soluciones y las características más importantes de su trabajo.

3.2.6 Evaluación

La evaluación se realiza a partir del módulo instruccional presentado en un CD, su exposición en clase y las actas quincenales. Los aspectos del módulo que valoramos son: la V de Gowin, los MMCC siguiendo criterios ya establecidos, las actividades propuestas, la calidad y variedad de los recursos, la justificación psicopedagógica y didáctica y la presentación clara y transparente de todo el trabajo en torno a un mapa conceptual realizado con el programa informático CmapTools.

En la exposición tenemos en cuenta, además de los contenidos presentados la facilidad para transmitir de forma clara y concisa los aspectos más relevantes de su trabajo.
Las actas quincenales posibilitan la evaluación continua del alumno porque permiten seguir de cerca el trabajo realizado por el grupo. De este modo el profesor puede detectar las dificultades y regular o adaptar el trabajo del grupo. A través de las actas el profesor puede conocer: la diversidad de tareas que realiza el grupo, las discusiones, debates, problemas que se plantean en el seno del mismo y también los cambios operados en el proceso de aprendizaje de los propios alumnos.

3.3 Evaluación de la experiencia.

Para evaluar todo el proceso se realiza un cuestionario dirigido a conocer la opinión de los alumnos sobre las ventajas de la metodología utilizada: Actividad grupal y trabajo autónomo y de la aplicación de las herramientas heurísticas antes mencionadas: MMCC y V de Gowin.

4 **Conclusiones**

En este trabajo se pone de manifiesto las ventajas obtenidas en la elaboración de un Módulo Instruccional utilizando MMCC, el programa informático CmapTools y las V de Gowin, a partir de la actividad grupal y el trabajo autónomo. Los mapas han permitido a los alumnos organizar de forma clara y precisa la información obtenida. Hacer visible la relación teoría práctica en un diseño instruccional, transformar el conocimiento tácito de expertos naturalistas en explícito a partir de entrevistas a los cuidadores del parque. Enlazar a los conceptos del MC, en cada una de las actividades, la información visual (vídeos , fotografías documentos sonoros, etc.) obtenida en sus visitas al parque. Se consigue así un modelo más completo del conocimiento construido.

Por otra parte el trabajo en equipo o trabajo colaborativo y autónomo de los alumnos les ha llevado a desarrollar una serie de competencias que les serán de mucha utilidad en su futuro profesional y que facilitarán a los alumnos, futuros profesores, a enfrentarse con éxito a los desafíos que conlleva el cambio de paradigma didáctico/pedagógico que implican la llamada Sociedad del Conocimiento y de la Información y el Espacio Europeo de la Educación Superior. Competencias, entre las que podemos destacar el desarrollo de la comunicación oral y escrita, la reflexión en cada uno de los elementos epistemológicos de la V de Gowin, la comprensión de las dificultades que surgen en el trabajo en equipo, y la transposición didáctica de los contenidos científicos al aula.

Además la elaboración periódica de actas por grupos de alumnos ha permitido a los profesores un control puntual y sistemático de la evolución de estos procesos en los alumnos, suministrando el feedback apropiado para la mejora de los mismos.

Finalmente del análisis de las respuestas de los alumnos al cuestionario de valoración final de la metodología utilizada se deduce el alto grado de satisfacción obtenido por los mismos, con especial énfasis en la virtualidad de la construcción de MMCC para la obtención de un aprendizaje más significativo.

5 Bibliografía

Albisu S, San Martín I. y González, F. (2003). Las Nuevas Tecnologías en la Enseñanza- Aprendizaje de la Geografía: Un ejemplo de aplicación a través de la elaboración de un módulo instruccional sobre el Parque de la Taconera. Actas del Congreso sobre la Enseñanza de la Geografía ante las nuevas demandas sociales. Toledo, pp. 169-177.

Cañas, A. J., Ford, K. M., Coffey, J., Reichherzer, T., Carff, R., Shamma, D., & Breedy, M. (2000). Herramientas para Construir y Compartir Modelos de Conocimiento basados en Mapas Conceptuales. Revista de Informática Educativa, 13(2), 145-158.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

González, F Mª and Cañas, A. J.(2003). Gonca Project: Meaningful Learning Using CmapTools, in Méndez, A., Mesa, J. A and Mesa, J.(Edits.*). Advances in Technology-Based Educaton. Towrd a Knowledge-Based Society. II International Conference on Multimedia ICT´s in Educaton*, pp. 747-750

González F. y Novak J. D.(1996): Aprendizaje significativo. Técnicas y aplicaciones.Cincel, Madrid.

Novak, J. D. y Gowin, D.B. (1988). Aprendieno a aprender. Barcelona. Martínez Roca

Novak J D.,González F M. (Editors). *Concept Maps: Theory, Methodology, Technology (Vol 1)* Proceedings of the First International Conference on Concept Mapping. Dirección de Publicaciones de la Universidad Pública de Navarra: Pamplona, Spain,(pp 359-365).

San Martín, I, Albisu, S. y González, F. (2004). *El mapa conceptual como agente facilitador de un currículum integrado en el Área de Conocimiento del Medio Natural, Social y Cultural.* En Cañas A. J. , Novak J. D. , González F. M. (Editors). *Concept Maps: Theory, Methodology, Technology (Vol 2)* Proceedings of the First International Conference on Concept Mapping. Universidad Pública de Navarra: Pamplona, España, (pp. 319-322)

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

APRENDIENDO UNA METODOLOGÍA PARA LA INTRODUCCIÓN DE MAPAS CONCEPTUALES EN LA ENSEÑANZA PRIMARIA; APOYADOS CON LA TECNOLOGÍA

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Abstract. Este trabajo se basa en una experiencia piloto llamada "**Grupo de Apoyo**", desarrollada por un Asesor del Programa Nacional de Informática Educativa (Preescolar, I y II Ciclos) del Ministerio de Educación Pública – Fundación Omar Dengo. El objetivo principal de la experiencia, es apoyar a los tutores de Informática Educativa de la provincia de Alajuela, Costa Rica, en la introducción de mapas conceptuales en la enseñanza primaria (Preescolar, I y II Ciclos). Dentro del desarrollo del mismo se presentan cuatro estrategias metodológicas, apoyadas en material concreto, semi-concreto y en recursos tecnológicos. La experiencia se realizó con tutores de informática educativa de las diferentes regiones educativas de la provincia de Alajuela (Alajuela, San Ramón y San Carlos), donde los participantes tuvieron la oportunidad de explorar las actividades, realizar puestas en común y dar las recomendaciones pertinentes a la propuesta. Para el desarrollo del mismo, se confeccionó un folleto de consulta y para realizar las actividades, acompañado de un disco compacto, el cual contiene el material para ser reproducido y poner en práctica las propuestas metodológicas con sus alumnos. Se pretende a través de esta experiencia, dar a conocer las apreciaciones de los participantes (74 tutores); tanto a nivel de lo vivenciado, valoración de las propuestas metodológicas, importancia de los mapas conceptuales dentro de la propuesta pedagógica del Programa Nacional de Informática Educativa (Preescolar, I y II Ciclos), socialización de conocimientos nuevos sobre la construcción de mapas conceptuales y pertinencia de los materiales proporcionados.

1 Introducción

El Programa Nacional de Informática Educativa, (Preescolar, I y II Ciclos) que ejecuta la Fundación Omar Dengo en forma conjunta con el Ministerio de Educación Pública, privilegia desde hace diez años la construcción de mapas conceptuales, dentro de la propuesta pedagógica del PRONIE MEP-FOD, Enfoque de Aprendizaje por Proyectos.[1] (EAP)

La construcción de mapas conceptuales dentro de esta propuesta, es considerada como un recurso estratégico que permite a los educandos iniciar un proceso de interacción e interiozación de ideas con los conocimientos previos de un tema curricular, acontecimiento o una situación en particular.

Tomando en consideración la propuesta del PRONIE (Preescolar, I y II Ciclos) y la importancia que esta da a la construcción de mapas conceptuales, el "Círculo de Asesores"[2] de la provincia de Alajuela, valora la necesidad de continuar apoyando a los tutores de Informática Educativa; en este proceso, a través de un taller llamado "**Grupo de Apoyo**[3]", con el propósito de intercambiar e enriquecer las estrategias para la introducción de mapas conceptuales en la enseñanza primaria y la articulación del mismo a la propuesta pedagógica del Programa en los centros educativos de las regiones de Alajuela, San Ramón y San Carlos.[4]

Para facilitar la organización de este espacio de intercambio, el equipo de asesores de Alajuela, asignó a un Asesor, para la elaboración de los materiales y puesta en práctica de la experiencia educativa. Para tal efecto; se preparó un folleto, titulado: "***Introducción de mapas conceptuales y su articulación con el Enfoque de Aprendizaje por Proyectos***" como recurso de consulta y guía de práctica para la recolección de datos e insumos, sobre estrategias para abordar los mapas conceptuales. Además se acompaña de un disco compacto con material de apoyo para desarrollar las actividades en un período de cuatro horas presenciales; y a la vez sirve de insumo para

[1] **(EAP):** "es una alternativa metodológica que integra las características del enfoque pedagógico construccionista, donde la construcción externa o producto elaborado por los aprendices, acompaña y enriquece la construcción mental que ocurre en su pensamiento. La libre elección de un tema para realizar un proyecto constituye en el rasgo distintivo para promover una experiencia de aprendizaje significativo" (4)

[2] **Círculo de Asesores:** Grupo de asesores especializados en Informática Educativa por regiones, que trabajan en equipo, con el propósito de apoyar los desempeños pedagógicos en el desarrollo de la propuesta pedagógica del PRONIE (Preescolar, I y II Ciclos).

[3] **Grupo de Apoyo:** "es un espacio que permite el intercambio entre asesores y tutores para el desarrollo de acciones pedagógicas con el fin de fortalecer el crecimiento profesional y pedagógico, que busca enriquecer el desarrollo del Enfoque de Aprendizaje por Proyectos". (1)

[4] **Regiones educativas:** se consideran a las áreas geográficas establecidas por el Ministerio de Educación Pública de Costa Rica, para atender administrativa los centros educativos del país. En el caso de Alajuela, San Ramón y San Carlos, se encuentran ubicadas en la provincia Alajuela, Costa Rica.

complementar la puesta en práctica de las ideas compartidas en este intercambio y continuar el proceso de autoaprendizaje.

2 Metodología de trabajo en el diseño y ejecución de la propuesta

2.1 Diseño de propuestas pedagógicas

El asesor asignado tuvo bajo su responsabilidad el diseño, organización, logística, ejecución y valoración de la propuesta pedagógica a desarrollar. Para elaborar la propuesta pedagógica, se habilitó un espacio de cinco días; distribuidos de la siguiente manera: tres días para el diseño de la propuesta pedagógica, un día para la presentación y valoración y otro para la depuración y reproducción de la misma.

Para el desarrollo de la propuesta pedagógica, **Grupo de Apoyo: "Introducción de mapas conceptuales y su articulación con el Enfoque de Aprendizaje por Proyectos",** se definieron los siguientes objetivos:

- Comprender la importancia de la construcción de mapas conceptuales, como estrategia pedagógica para la expresión, comunicación y organización de ideas.
- Identificar aspectos relevantes para la construcción de mapas conceptuales.
- Analizar la importancia de la articulación del mapa conceptual con la estrategia pedagógica del Enfoque de Aprendizaje por Proyectos.
- Interactuar con algunas estrategias pedagógicas, para la introducción de mapas conceptuales en Preescolar, I y II Ciclos.

2.2 Proceso de divulgación para la participación en el Grupo de Apoyo

El equipo de Asesores de Alajuela, programó para inicios de este año, una reunión con los tutores de Informática Educativa de la región, con el fin de compartir acciones a desarrollar durante el año 2006. Para esta reunión, se estableció en la agenda, la participación libre a la actividad: **Grupo de Apoyo**: "**Los mapas conceptuales y su articulación con el Enfoque de Aprendizaje por Proyectos**".

En la siguiente ilustración se observan los diversos procesos desarrollados; desde la matrícula de los participantes; hasta la organización logística y administrativa, para la ejecución del "Grupo de Apoyo".

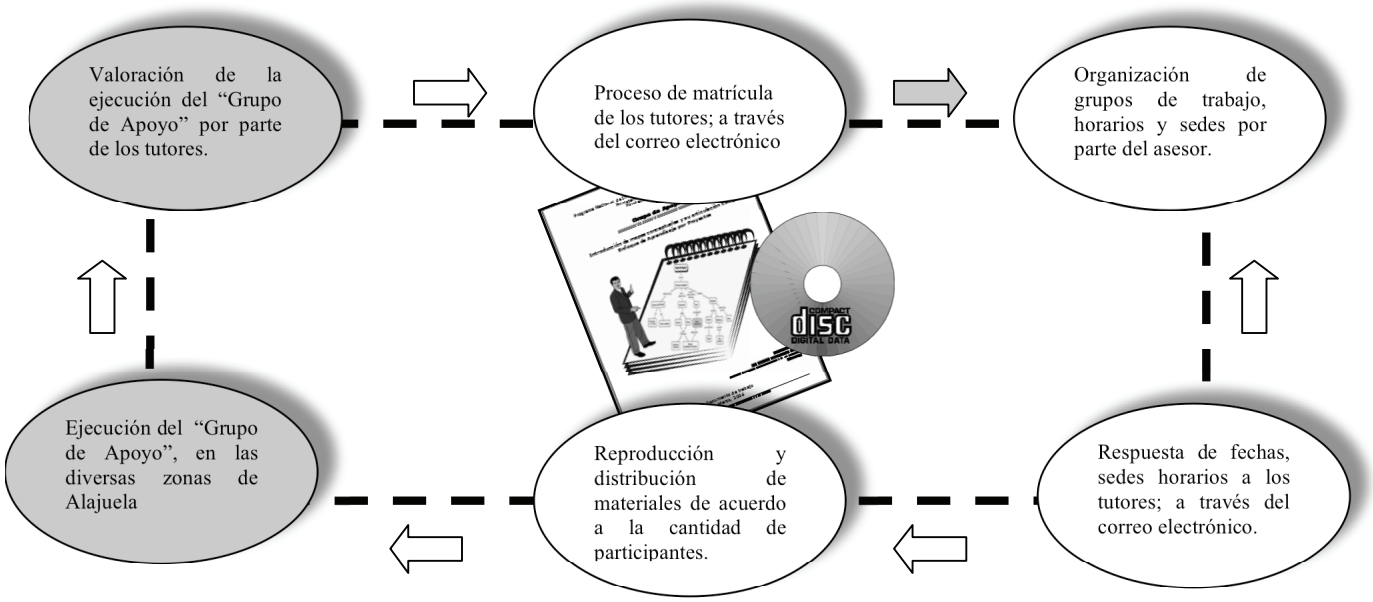


Figura 1. Proceso ejecutado para el desarrollo del "Grupo de Apoyo"

2.3 Ejecución de la propuesta

Para efectos de este trabajo, se tomó en cuenta los dos últimos procesos (**ejecución y valoración**) de la totalidad de la experiencia vivenciada, donde los participantes tuvieron la oportunidad de:

- Compartir bibliografía existente acerca de la construcción de mapas conceptuales y los términos: **enlaces**, **concepto** y **proposición**.
- Elaborar un mapa conceptual; utilizando un conjunto de palabras definidas en el documento, y la comparación con un mapa conceptual previamente establecido en el documento.
- Explorar en pequeños subgrupos alguna propuesta metodológica, para la introducción de mapas conceptuales en la enseñanza primaria, Preescolar, I y II Ciclos.
- Retomar en forma teórica, la propuesta metodológica del PRONIE (Preescolar, I y II Ciclos) y la articulación de los mapas conceptuales; dentro del Enfoque de Aprendizaje por Proyectos.

2.3.1 Primera etapa:

Consulta bibliográfica sobre la construcción de mapas conceptuales

En esta primera etapa del taller, los tutores de Informática Educativa tuvieron la oportunidad de consultar bibliografía sobre la elaboración de mapas conceptuales, a través de un artículo con actividades, que fue incorporado en el documento de trabajo, tomando como referencia, algunos aspectos metodológicos y de estructura establecidos en diferentes libros; tales como: "**Los mapas conceptuales: una técnica cognitiva para ayudar a la calidad de la educación**", del Proyecto SIMED, Ministerio de Educación Pública de Costa Rica y "**Aprendiendo a Aprender**" de Joseph D. Novak y D. Bob Gowin. Estas actividades permitieron a los tutores, intercambiar ideas sobre los conocimientos previos y los obtenidos a través de la lectura del artículo, para retomar la construcción de los mapas conceptuales.

2.3.2 Segunda etapa:

Construcción de un mapa conceptual en pequeños grupos

Con el propósito de poner en práctica la bibliografía consultada y los conocimientos previos de cada tutor, se conformaron subgrupos de trabajo para construir un mapa conceptual con los siguientes conceptos: **plantas, vertebrados, conejo, agua, herbívoros, zacate, peces, algas, huesos y animales**. Para la construcción de este mapa, se utilizó la herramienta MicroMundos[5], utilizando el programa: "**Editor de Mapas**[6]", el cual permite ingresar palabras en una caja de texto, (conceptos-enlaces), las cuales se introducen a través de botón en la página; para luego elaborar el mapa conceptual. Posteriormente los participantes realizaron una comparación entre los mapas conceptuales elaborados por ellos y el que se encuentra en el anexo N. 2 del folleto de actividades del taller.

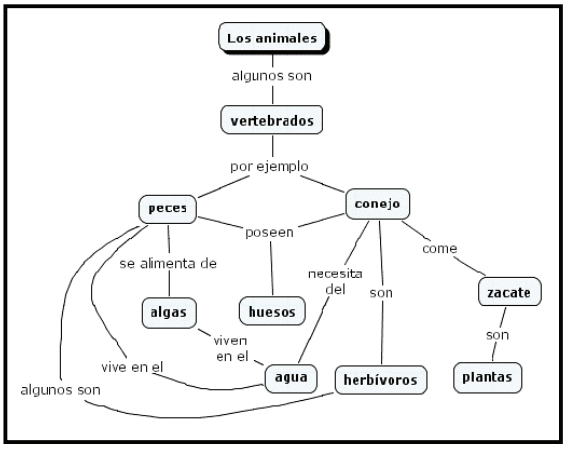


Figura 2. Mapa conceptual del tema "Los animales" Elaborado por: Lic. Donald Rodríguez Vega. Asesor PRONIE (Preescolar, I y II Ciclos)

2.3.3 Tercera etapa:

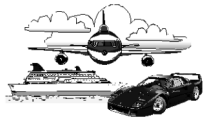
[5] **MicroMundos:** "…es una versión multimedia del Lenguaje de Programación Logo, es una herramienta de aprendizaje creada por el Dr. Seymour Papert, quien ha estado vinculado con el Laboratorio de Medios del Instituto Tecnológico de Massachussets. MicroMundos como herramienta, permite crear un ambiente de aprendizaje creativo en el que las personas pueden formular y probar ideas, crear imágenes, simular diferentes fenómenos, eligiendo desde caminos más heurísticos, abiertos y creativos hasta caminos más algorítmicos y estructurados como el el caso del uso de la programación por procedimientos". (3)

[6] **Editor de mapas**: Herramienta construida en MicroMundos por Efraín López Morales. Productor Académico de la Fundación Omar Dengo.

Exploración de las propuestas metodológicas para introducir los mapas conceptuales en la enseñanza primaria.

Considerando que en los Laboratorios de Informática Educativa; se atiende niños desde la enseñanza Preescolar, I y II Ciclos, se propone la exploración de cuatro propuestas metodológicas, para la introducción de mapas conceptuales, tomando en cuenta los siguientes aspectos:

1- Propuestas metodológicas con temas, que en la medida de lo posible, sean de interés para los niños.
2- Variedad de temas con el propósito de que el docente ofrezca nuevas estrategias y materiales en el abordaje de la construcción de mapas conceptuales.
3- Nivel de lecto-escritura de los niños.
4- Conjunto de conceptos en MicroMundos que deben conocer o explorar los niños, antes de desarrollar la propuesta metodológica.

	Preescolar	**I Ciclo**		**II Ciclo**
Nivel	**Transición Materno Infantil**	**Primero**	**Segundo Tercer**	**Cuarto Quinto Sexto**
Tema abordado	 **El pez**	 **Cuento: La Cenicienta**	 **Medios de transporte**	 **La casa**
Conocimientos de lecto-escritura	Los niños no han empezado el proceso de la lecto-escritura, por lo que se propone la introducción de mapas conceptuales, a través del tema "**El pez**" utilizando juguetes.	Los niños están iniciando el proceso de lecto – escritura, por lo que se propone la introducción de mapas conceptuales a través de un cuento.	Los niños ya han iniciado el proceso de la lecto – escritura, por lo que se propone la introducción de mapas conceptuales a través del tema: **Medios de Transporte** utilizando conceptos conocidos por la mayoría de los estudiantes.	Los niños ya tienen un buen nivel de la lecto – escritura, por lo que se propone la introducción de mapas conceptuales a través del tema la "**casa**" que permite aprender el proceso de clasificación y jerarquización de los conceptos.
Conocimientos previos en Micromundos (*)	Utilización de algunos recursos del centro de dibujo: lápiz, color entre otros.	Utilización de algunos recursos del centro de dibujo: lápiz, color entre otros. Creación de tortugas Disfrazar una tortuga Utilización del recurso de audio (Grabar palabras).	Utilización de los recursos del centro de dibujo. Manipulación del Editor de Mapas. Creación de tortugas Disfrazar una tortuga	Utilización de los recursos del centro de dibujo. Manipulación del Editor de Mapas. Creación de tortugas Disfrazar una tortuga

(*) Puede ser que los niños tengan estos conocimientos previos, sino es así; se debe introducir los conceptos o herramientas, para lograr el cumplimiento de las actividades propuestas.

Tabla 1: Propuestas metodológicas elaboradas para la construcción de mapas conceptuales

A- Propuesta metodológica para Preescolar

La propuesta metodológica para introducir a los niños de enseñanza Preescolar en la construcción de mapas conceptuales, toma como tema generador: "**El Pez**". Partiendo de un conjunto de juguetes relacionados con el tema del pez como: **barco, algas, pescados, caña de pescar, muelle,** entre otros y de preguntas establecidas por las docentes, los niños van construyendo en el suelo, un mapa conceptual sobre el tema, uniendo las relaciones con paletas para helados.

Es importante destacar que para desarrollar esta propuesta metodológica, el docente debe elaborar con anterioridad un conjunto de preguntas con un orden específico con relación a los juguetes; para cuestionar a los niños y orientar el proceso de construcción del mapa conceptual, estableciendo relaciones y jerarquías pertinentes.



Fotografía 1. Construcción de un mapa conceptual, sobre el tema del pez con juguetes e ilustraciones, por tutores de Informática Educativa de Alajuela

Después de realizar estas actividades, los niños interactúan con un archivo en MicroMundos, el cual propone retomar el mapa conceptual del tema del pez, a través de un conjunto de figuras insertadas en la página del programa para realizar las relaciones, utilizando el lápiz del centro de figuras.

B- Propuesta metodológica para Primer Grado

En el primer grado del la enseñanza primaria, se propone la introducción de los mapas conceptuales, por medio del cuento: "**La Cenicienta**", teniendo en consideración que el cuento lo conocen la mayoría de los estudiantes. Para empezar se hace una presentación del cuento, a través de un proyecto de MicroMundos que contiene el cuento en forma animada.

Posteriormente se reparte a los niños, un conjunto de ilustraciones con todos los personajes del cuento y algunos elementos como: **la casa, el castillo, el carruaje** entre otros, para empezar a reconstruir el cuento. La docente hace un repaso con los estudiantes, pregunta sobre el personaje o elemento del cuento, con el propósito de detonar una red de relaciones.

Los niños construyen el cuento en el suelo, orientados por preguntas, elaboradas previamente por los docentes.

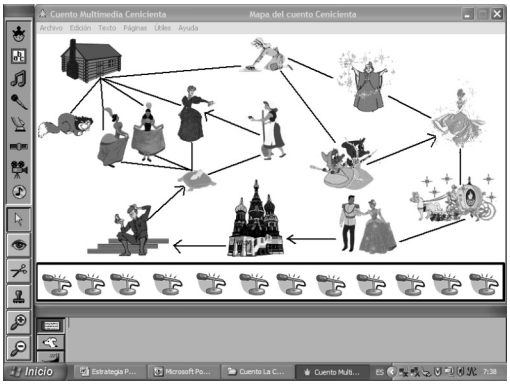


Figura 3. Ejemplo de un proyecto en MicroMundos, donde los niños realizan la reconstrucción del cuento: La Cenicienta.

Después de realizar la construcción del cuento en el suelo, los niños reconstruyen el cuento en formato electrónico; por medio de un archivo de MicroMundos, que les permite interactuar con las figuras, para realizar las relaciones entre los conceptos, utilizando el lápiz del centro de figuras, también puede elaborar grabaciones multimedia, para luego incorporarlas al mapa conceptual.

C- Propuesta metodológica segundo y tercer grado

Para los niveles de segundo y tercer grado, se propone la introducción de mapas conceptuales, con el tema: "**Medios de Transporte**", esto debido a que es un tema conocido por la mayoría de los niños y que está en el plan de estudios. En este tema se hace más énfasis a la relación de un concepto con varios conceptos, por ejemplo: el concepto "**carro**" con los conceptos, **combustible, batería, llantas**, entre otros.

Para el abordaje del mismo, se propone realizar un "**juego**", donde los niños forman dos subgrupos; uno que tendrá a su cargo las ilustraciones de los medios de transporte y el otro; ilustraciones de objetos que tienen alguna relación con uno o varios transportes. Para iniciar el juego, el docente, solicita a un niño presentar un medio de transporte e indicar; ¿**Por cuál medio transita**?, **el agua, la tierra o el aire** y luego; después de dar la respuesta a la interrogante, se le solicita al estudiante, colocar la ilustración en el suelo. Posteriormente un niño o varios niños del otro grupo, muestran ilustraciones de objetos que tienen relación con ese medio de transporte y contestan al docente las siguientes interrogantes: ¿**A qué medio de transporte pertenece**?, ¿**Qué función cumple ese objeto en el medio de transporte**?, después de contestar las preguntas con ayuda de sus compañeros, colocan en el suelo las ilustraciones, realizando las relaciones entre los conceptos, con las paletas de helados y carteles con las palabras de enlace.



Fotografía 2. Directora y tutora de un centro educativo de Alajuela, construyen relaciones entre los conceptos del tema: Medios de transporte.

Luego de efectuar esta actividad, se propone a los niños realizar varios ejercicios en un proyecto de MicroMundos, en el cual deben relacionar conceptos y palabras de enlaces para formar proposiciones. Las páginas del proyecto tienen un orden de complejidad de los ejercicios, hasta llegar a una página donde se debe completar palabras de enlace a un mapa conceptual sobre el tema en estudio.

D- Propuesta metodológica para II Ciclo

Para el II Ciclo de la Enseñanza Primaria, se propone el tema: "**La casa**" para la introducción de mapas conceptuales; debido a que es un tema que permite trabajar ampliamente la **clasificación** y **orden de jerarquía** de los conceptos.

Para el desarrollo de las actividades, se brinda a los niños ilustraciones con algunos de los aposentos de una casa: **dormitorio, cocina, sala, baño, cuarto de pilas**, entre otros, y un conjunto de ilustraciones con diversos elementos que se encuentran en la casa como**: silla, mesa, teléfono, cama, jabón, televisor** entre otros.



Fotografía 3. Ejemplo de un mapa conceptual sobre el tema de la casa, construido por tutores de Informática Educativa de Alajuela

Se inicia un primer proceso para la **clasificación de conceptos**; que consiste en colocar las ilustraciones de los aposentos de la casa (dormitorio, sala, comedor, cocina, baño) en los extremos del aula. El docente pide a los estudiantes, definir a que aposento pertenece la ilustración que tiene asignada; por ejemplo: **la cama,** la cual pertenece al aposento, **el dormitorio**; el estudiante que tiene la ilustración, se ubica en la esquina estratégica donde está la ilustración del aposento; este ejercicio se realiza varias veces, donde los estudiantes tienen que intercambiar las ilustraciones, para practicar el ejercicio de clasificación.

Posteriormente, la docente coloca la ilustración de una casa en el suelo, e invita a los niños a realizar un recorrido imaginario por una casa, orientada por varias preguntas tales como: ¿**Cuando entramos a una casa, qué observamos de primero**?, después que otras cosas podemos ir observando; ¿**Estará el baño en la entrada principal de la casa**?; después de realizar el recorrido imaginario, invitamos a los niños a reconstruir la actividad a través de un mapa conceptual en el suelo, utilizando paletas de helados para hacer la relaciones entre los conceptos y carteles para las palabras de enlace. Después de esta actividad, los niños exploran un archivo en MicroMundos, para retomar la construcción de proposiciones (conceptos y palabras de enlace) sobre el tema en estudio. Por último se le propone construir un mapa conceptual sobre la casa o un aposento de la casa, utilizando la herramienta en MicroMundos: "**Editor de Mapas**".

E- Socialización de las propuestas metodológicas por parte de los subgrupos de trabajo.

Debido al poco tiempo para el estudio y exploración de las propuestas; se propone como cierre de la tercera etapa, una presentación de la exploración de cada propuesta, por parte de cada subgrupo del trabajo. En esta presentación los integrantes del subgrupo, se organizan para dar a conocer la propuesta al resto del grupo, considerando los siguientes aspectos: ¿En qué consiste la propuesta?, ¿Qué materiales se utilizan? y las recomendaciones pertinentes de acuerdo a la experiencia vivenciada.



Fotografía 4. Tutores y Asesor de Informática Educativa en la presentación de las propuestas metodológicas, por cada uno de los subgrupos de trabajo

4- Valoración de la propuesta por parte de los tutores

Como proceso de cierre a la actividad del "**Grupo de Apoyo**", se entregó a cada uno de los participantes un instrumento de valoración, con el propósito conocer sus apreciaciones sobre lo vivenciado en la experiencia, las propuestas de actividades y el contenido de los materiales.

Respecto a la vivencia de los tutores en el desarrollo del "Grupo de Apoyo" se considera que fue un espacio para…

- Reforzar conceptos para la construcción de mapas conceptuales.
- Comprender diferentes tipos de mapas conceptuales y diferenciarlos de un esquema.
- Conocer nuevas técnicas metodológicas dinámicas para la introducción de mapas conceptuales
- Enfocar la introducción de mapas conceptuales de acuerdo a distintos niveles.
- Encontrar alternativas para mejorar la mediación pedagógica en la introducción de mapas conceptuales.
- Generar un ambiente de cooperación y aprendizaje agradable en el desarrollo de la propuesta del taller.
- Aprender en forma individual y colectiva, debido a la metodología y mediación utilizada.
- Brindar material pertinente para introducir los mapas en una forma divertida y motivadora.
- Crecer en el ámbito personal y profesional.

Respecto a la importancia de los mapas conceptuales en el EAP, se considera que…

- Permite al estudiante, docente y tutor, enfocar mejor el tema en estudio, aclarando ideas y demostrando habilidades.
- Permite expresar brevemente ideas de un tema del currículo.
- Facilita a los estudiantes plasmar conocimientos previos y ya investigados para su proyecto.
- Permite al niño, guiar sus ideas, profundizar sobre varios conceptos y además ser ordenado.
- Guía la proyección y representación del proyecto computacional.
- Facilita la distribución de tareas de las compañías de producción[7] y ayuda a interiorizar conceptos
- Es una buena estrategia para organizar y orientar a los niños en el desarrollo del EAP.
- Es una herramienta muy útil, en cuanto organiza y orienta en el momento de la construcción del proyecto en Micromundos.
- Permite dar un norte a las tareas de cada una de las compañías de producción.
- Permite el avance y el desarrollo de un buen proyecto, propuesto por cada compañía.

[7] **Compañía de producción:** "es una modalidad de trabajo y aprendizaje, que se caracteriza por reunir un grupo de personas a quienes une la atención de lograr propósitos y metas definidas en común. Para el logro de dichas metas, sus integrantes negocian, se asignan responsabilidades, dan seguimiento a sus procesos de aprendizaje y producción; al tiempo que comparten con otras compañías sus logros y producciones". (3)

- Sin los mapas conceptuales, no tendría sentido el desarrollo de la propuesta del PRONIE (Preescolar, I y II Ciclos) en las actividades desarrolladas en los Laboratorios de Informática Educativa.

Nuevos conocimientos adquiridos para la introducción de los mapas conceptuales fueron…

- Ser más creativo y tener nuevas ideas y formas para introducir los mapas conceptuales a los niños.
- Ampliar en el uso en las diferentes materias académicas de la Enseñanza Primaria.
- Los mapas deben enriquecerse en diferentes momentos del EAP.
- Utilizar más el recurso tecnológico para apoyar la introducción de los mapas conceptuales.
- Ampliar las estrategias para trabajar los mapas conceptuales con los estudiantes.
- Entender que por medio de otros recursos, los niños aprenden a construir mapas conceptuales.
- Tener nuevas ideas, para el proceso que deben llevar los mapas conceptuales en los distintos niveles.

La evaluación de la secuencia de la propuesta de actividades en el desarrollo del "Grupo de Apoyo" se considera…

- Muy creativo con actividades bastantes lúdicas, para trabajar los mapas conceptuales.
- Flexible ya que permite adaptar las propuestas metodológicas al nivel e intereses del grupo escolar.
- Adecuada, porque se interactúa con el material, utiliza la computadora y se puedan aclarar dudas a los estudiantes, cuando interactúan con la teoría y tecnología.
- Adecuada, ya que primero se leyó para comprender, luego se puso en práctica y por último se socializó.
- La actividades se proponen de lo más sencillo, a lo más complejo.
- Pertinente, porque puede orientar a tutores que son nuevos en el PRONIE (Preescolar, I y II Ciclos).
- Adecuada porque va de lo concreto a lo abstracto y además permite compartir con los demás compañeros, los aprendizajes adquiridos, retroalimentando con ideas y sugerencias.
- Material de excelente calidad, que servirá para consultar y desarrollar actividades constantemente.

En los apartados de la evaluación, donde se solicita a los participantes anotar, sobre actividades que modificaría, eliminaría o agregaría a la propuesta, la mayoría de los participantes, escribieron que "**ninguna"** y a la vez otros manifestaron expresiones como las siguientes: "**Ninguna, todas son geniales, solo de saberlas acomodar al momento y nivel del grupo**", "**Ninguna todas están muy buenas**", "**Por el momento ninguna, todas me pareció excelente**", "**Me parece que está bien trabajado y organizado…**", "**Todavía no sé, tendré que verlo con mucho más detalle**" entre otras.

5. Referencias

1- Círculo de Alajuela. (2006) Documento: *Lineamientos Pedagógicos y Administrativos; para tutores de Informática Educativa, de las zonas: Alajuela, San Ramón y San Carlos*. PRONIE (Preescolar, I y II Ciclos) Ministerio de Educación Pública. Fundación Omar Dengo. San José, Costa Rica. Febrero, 2006. p.15

2- Joseph D. Novak. (1984) ***Aprendiendo a Aprender***. Traducción de Juan M. Campanario y Eugenio Campanario. Ediciones Martínez Roca, S.A. Enric Granados. Barcelona.

3- Programa Nacional de Informática Educativa MEP – FOD (Preescolar, I y II Ciclos). (2005). *El aprendizaje en ambientes informatizados. Módulo Introductoria para docentes de la Modalidad: "Informática Educativa en el Aula"*. San José, Costa Rica.

4- Programa Nacional de Informática Educativa MEP – FOD (Preescolar, I y II Ciclos). (2001). ***Aproximación Conceptual***. El ambiente de Aprendizaje Informatizado en el Contexto PIE-MEP-FOD Una vivencia teórica – práctica. San José, Costa Rica. Febrero 2001. p.10

5- SIMED. (1997). *Los mapas conceptuales: una técnica cognitiva para ayudar a la calidad de la educación*. Sistema Nacional de Mejoramiento de la Calidad de la Educación Costarricense. Ministerio de Educación Pública. Costa Rica.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

CHARACTER AND PLOT NODES: WRITING FICTION WITH CONCEPT MAPS

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Abstract: Using literary analysis as a starting point, my creative writing students begin by "reverse engineering," or "disassembling," stories to analyze how their "parts," i.e. plot, character, setting and language, fit together structurally. Reading and constructing concept maps of these structures gradually deepen student understanding of both the form and the content of fiction. Midway through this process, we play constructivist "freeze-frame" games with the film *As Good As It Gets*, for example, to demonstrate to the students how much they already know about story and its character and plot structure. Finally, creative writing students are invited to complete scaffold maps for their own and their peers' nascent stories to complicate their characterization and plot structures. While this work establishes that literature and writing also have their domain, content and structure, despite the misapprehensions of many, it also enhances our students' ability to weave a convincing tale from the "characters" and incidents of their own lives.

1 Introduction

An old text of mine, *Reading poetry: an introduction* (1996) juxtaposes philosopher Immanuel Kant's distinction between *Kunst* (art) and *Wissenschaft* (science) with the poet William Wordsworth's claim "we murder to dissect" (qtd. in Furniss & Bath, p. 26). In fact, this very old philosophical schism between art and science, and Wordsworth's very dire Romantic reaffirmation of it, thrives everywhere in our Western culture still. This includes my recent research into the uses of concept mapping in academic studies. Rather than repeating the meta-analysis discussed in a separate paper[1], let me just summarize. An amazing array of researchers' dissertation abstracts discussed and affirmed the rigorous structure of concept mapping in such famously "content-oriented" domains as math and science, while far fewer researchers explored the structural uses of concept mapping in such infamously "non-content" domains as literature and writing. Focusing on the inspiration aspect of writing, even those in my own domain, in other words, tend to ignore the matter of structure. After all, if you have no concepts to teach, to learn, to inspire, you need no such structural device as a concept map. In fact, there are still those Wordsworthian Romantics among us who believe emphasis on structure to be anathema to the inspiring Muses of literature.

Yet, another famous poet, William Carlos Williams, bridged this theoretical gap between content needing structure and non-content needing none, when he wrote, "A poem is a small (or large) machine made out of words" (1969, p. 256). For him, as for me, writing deals with both content and structure. Teaching at a very technically-oriented university, I find myself in a unique position to "sell" this idea to my budding math- and science-oriented creative writing students in the form of reverse engineering story, for instance, as inspiration to their own creative writing endeavors.

2 From Literary Analysis to Creative Writing

My content is the structural arrangement of fiction devices such as plot, character, setting and language. After a general introduction to these concepts, students apply them in creating their own concept maps based on specific sample stories assigned as readings. However, fiction is not, to paraphrase another poet, criticism in reverse (Matthews, qtd. in *The practice of poetry*, 1992, p. 18). Students, therefore, need further concept mapping practice to segue from reverse engineering to applying these lessons to their own stories.

2.1 Literary Film Analysis as Reverse Engineering of Characterization

Recognizing the efficacy of contrasting characters in the stories of professional writers can help students to re-think and expand their own limited cast of characters to help them start, at least, to think like real writers. Moreover, a literary analysis of the contrasting characters in *As Good As It Gets* helps students to see the structural logic of such devices as character foils. See Figure 1, below for the following discussion of character and using these insights to add new characters to original fiction. Reorganizing the linear story-telling of the film helps to clarify character foils by demonstrating graphically both the opposing and similar aspects of the two main characters, Carol the

waitress and Melvin the writer. Such maps make it clear to students that the concept of foils is both more complex and more interesting than the simple binary oppositions they often assume.

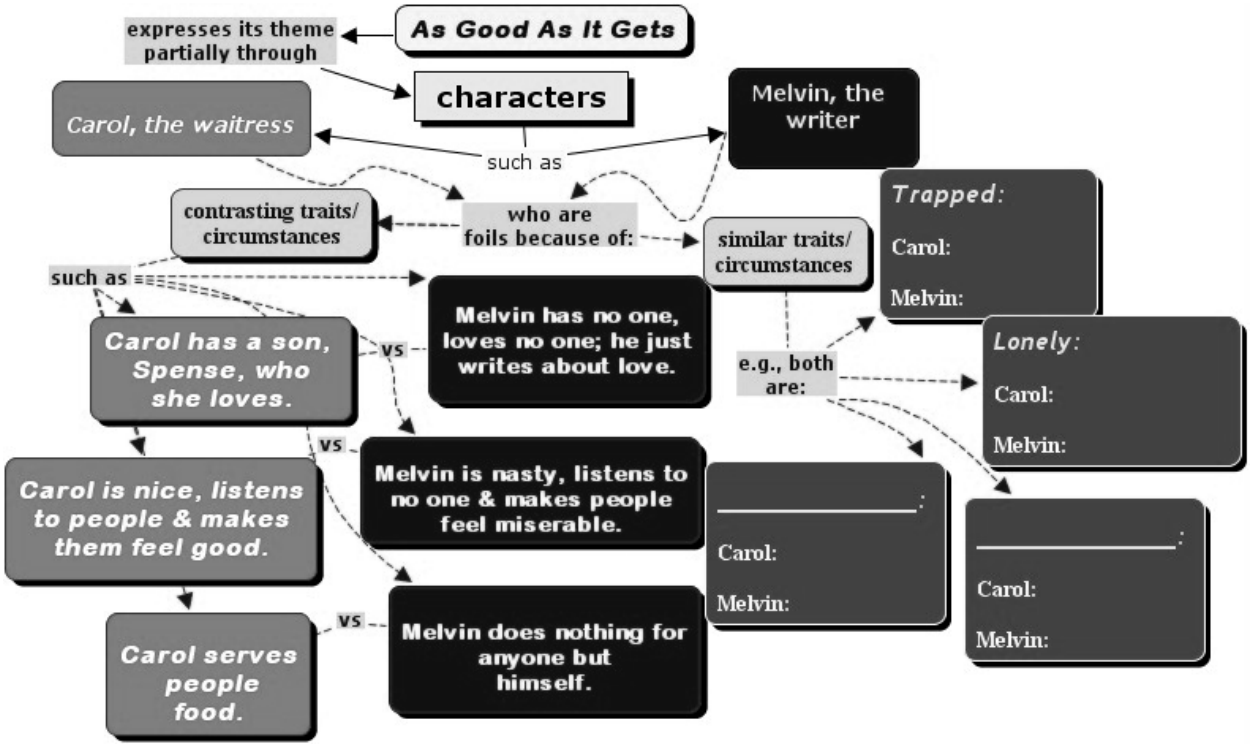


Figure 1. This map stresses the creation of successful foils through shared and contrasting qualities and circumstances, while leaving blanks for group discussion and completion.

For instance, without anything at all in common, Carol and Melvin would never meet. Beyond the obvious factor that both must make a living and both must eat, the characters have their common "entrapment" to bring them together, i.e. because she has no money, Carol works as a waitress in a busy Manhattan coffee-shop; because he has OCD (obsessive-compulsive disorder), Melvin must eat at this same coffee-house, always. This puts each in the other's way. What's more, it helps to emphasize the poignant and ironic loneliness each feels amidst the insanely crowded city bustle. Note also that the blanks left in some of the concept boxes allow the students to collaborate on their completion. This helps the class segue from teacher-generated, instructional maps to student-completed scaffold maps. It also prepares them to apply these concepts to the creation of their own characters. Good fiction, despite the preconceived notions of new writers, starts not with plot, but with the structure of characters and the wants and needs which bring them together, as well as those that pull them apart.

Figure 2, which follows, adds a few simple plot elements to the mix. Note also that these maps deal with destiny, a concept which many students, especially young Americans, ignore. By neglecting fate in the form of all the ungovernable givens we're born into, family, wealth or lack thereof, intelligence or lack thereof, and nationality, for instance, students limit the trouble they can create for their characters. Showing them these aspects in an extant story can start them thinking about creating more interesting characters from the raw material of their lives by considering the intersecting network of choice and chance we all represent for each other. Reversing the "chance" and "choice" concepts for Carol and Melvin, furthermore, subtly implies that the balance of chance and choice is not equal for all, rendering character interplay more realistic and opening up more opportunities for trouble – no trouble, no story – and for conflict. Finally, the map answers one question that has come up in teaching this film as character/plot analysis; why doesn't Carol do something about her life instead of just staying stuck? Such graphic inclusions as concept boxes on choice and chance inspire students to create more credible problems for their characters to overcome, compensating for their tendency to "rush" toward an easy ending for flat characters with insufficient conflict.

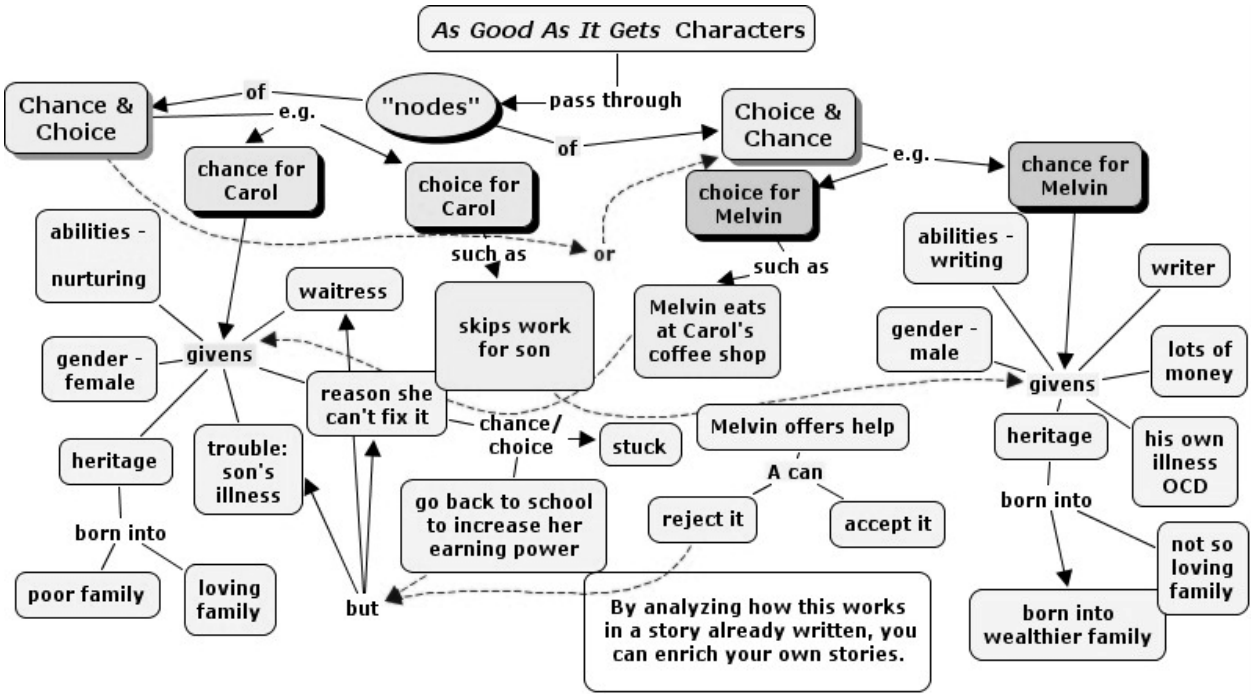


Figure 2. This teacher-generated map incorporates plot into character discussion by including concepts of chance and choice

2.2 More on Intersections of Character and Plot Structure

However, the reverse engineering of fiction already invented, because it starts with the foregone conclusion of a completed plot and completed characters, can, for some student writers, close down possibility in creative writing. At the same time, reverse engineering a story with a foregone conclusion can preclude consideration of real choice as the characters move through their own fictive lives. Ignoring choice also limits our belief in the characters' humanity, which, in turn, impedes our creation of a real bond of empathy. Rather than putting themselves in the place of these characters, students may stand apart, looking down from the height of their youthful egotism, condemning characters for their stupid mistakes. This makes sense, in a way. There is a tendency in this culture of individualism to blame the victims for their own suffering. After all, if they brought it all on themselves, all one needs do is avoid making such idiotic mistakes and nothing bad will ever happen to you. At least, this is one way to explain the lack of empathy in some students' responses. While it is understandable at a certain level, it is hardly in the humanistic spirit of communication through fiction and literature in general. If one fails to identify with characters in their fictive world, where are Aristotle's terror and the pity? Where is the catharsis? Part of teaching is recognizing our students' misconceptions, then helping them to see, and, thus, overcome them. In the spirit of constructivism, we must expose what our students believe or think they already know about life to fit new ideas and modes of experience, such as empathy, into their knowledge schemas.

As such, manifesting choice and chance in such concept maps truly helps raise the discussion to a more objective, literary level, while helping to alleviate a more important problem created by this lack of empathy in the students' own creative endeavors. Without the ability to empathize with **all** their characters, students fail to grant them, especially those characters representing "bad guys," any convincing motivation or interiority.

Figure 3, below, introduces another plot element for the students' consideration, that of genre, such as redemption story and romantic comedy, to the discussion of character and characterization. Note also that characters are shown to have interdependent assets and needs that help to draw them together, while, at the same time, causing them to come into conflict with each other.

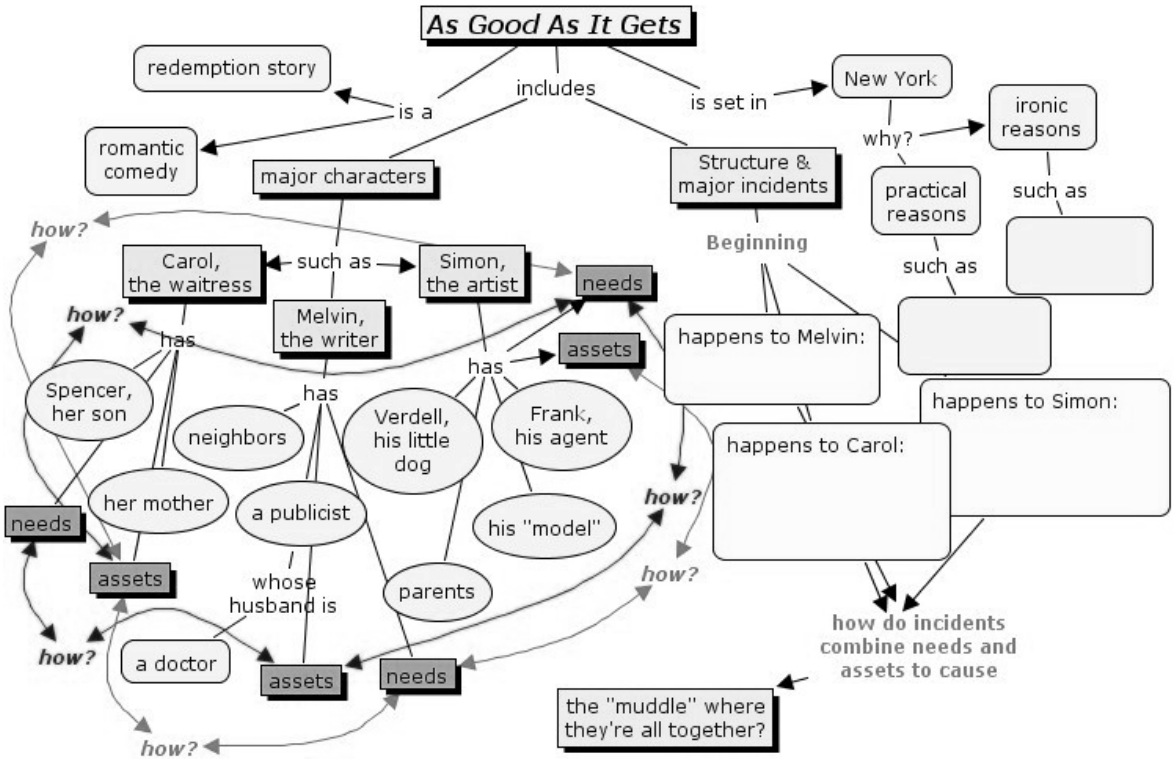


Figure 3. Teacher-generated map showing some intersections of character and plot with blanks for group discussion and completion

2.3 Node Heuristic of Plot Analysis and Creation

Working with creative writing concept maps helps to bridge the gap between analysis and creativity, between showing students how to reverse engineer and write about a story and to learn, from these same stories, plots and characters, how to transform their own experiences into fiction.

Adapting literature concept maps for use in creative writing classes revealed one possible way to help students make the leap from analysis to creative plot construction by highlighting real, creativity-blocking problems with the way we discuss literature. For instance, in discussing plot in literary analysis, we tend to focus on such terms as "turning points." However, concept mapping practice reveals a more complex pattern. For instance, those points in time where fate and character interact to force choice and change look more like "nodes" than turning points, since each character faces choices at these points and different choices for each at each node would move the plot in a different direction. The implications of this conceptual change are far more meaningful and interesting, especially in terms of teaching creativity, than they may, at first, seem. The concept of "turning points" implies a few cataclysmic events. It also suggests merely plot-driven stories where one or two events cause an inevitable, although eventual, conclusion. On the other hand, emphasis on structural nodes in a story's plot implies the many, possibly small, character-driven choices leading to other nodes and other choices, which altogether form a "neural network" of possibility. Rather than inevitability and the foregone conclusions of pure genre work, therefore, we have the more creative and humanistic series of choices that can support the construction of believable stories. In my classroom experience, this moves creative writing students toward a more carefully constructed convergence of circumstance, character and choice. In other words, nodes can act as a more open-ended system than the closed and limited concept of **the** turning point or points in a story, since they suggest a myriad of shifting, alternative possibilities

3 Moving Beyond Reverse Engineering

Once students have accepted the convergence of choice and chance, character and happenstance, in a successful story such as *As Good As It Gets*, they seem to feel freer to "play" more with the elements of their own lives that they always wish to transform into stories. This is fine; it gives them a place to start. However, by sharing with them these "tricks of the trade," as it were, we can give them the structural wherewithal to go on from there rather than settle for the rather formless reality of real-life. As Mark Twain wrote, fiction is harder than real life; fiction has to make sense. This is where the structure of concept mapping helps. In Figure 4, below, students are presented with a similar scaffold of choice and chance, with blanks for their own characters. This map can be used separately or in conjunction with other character maps. (See Figure 5, for example.)

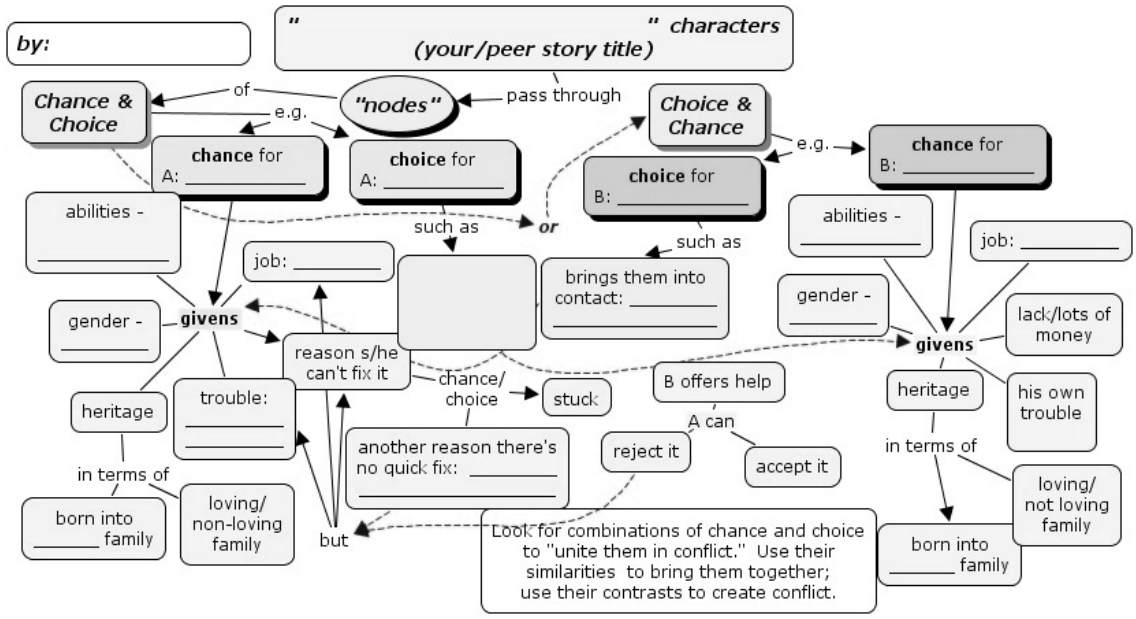


Figure 4. Scaffold map for student completion to add character and/or incidents to peer or their own stories

Using maps, students can play with extant plots, and then transform that same play into an analysis of their own life-stories to unearth alternative possibilities along the nodes of change. Furthermore, finding the nodes of plot and character that make a real-life story mundane or too predictable, for instance, can help a student's creativity break free of its real--life bonds. Looking at these same nodes also helps them to add new and contrasting characters that lift the plot from the foregone happy ending of their own survived conflicts to some less predictable, and, undoubtedly, more interesting, conclusion. Naturally, at the same time, our studies in genre will help steer students clear of the Scylla and Charybdis of tedium and melodrama.

3.1 Teacher- to Student-Generated Concept Maps – Scaffolds to Structural Creativity

The following exercise combines literary plot and film analysis of *As Good As It Gets* with concept mapping and "what if" games. As unlikely a romantic couple as Jack Nicholson and Helen Hunt might be, the acting is superb and the dialog is crisp and witty, and, most important of all, Nicholson's character, Melvin the writer, is an hysterically, nasty-mouthed man, who the students love, in a convincing redemption story. All of this keeps the students' interest while giving the story the palpably "mappable" structure, in terms of both plot and character, necessary for a heuristically useful concept map.

After screening enough of the film to establish the main characters and their problems, I like to stop at an important "chance/choice" node and ask what happens next. For instance, I like to stop the film right after Melvin has offered Carol help with her son's illness and ask, "OK, help has been offered . . . will she accept?" Almost invariably, whether they've seen the film or not, students answer, "Yes, she does." Asking why effectively

combines the Socratic method of teaching with constructivism, since their own answers tend to prove how much they already know about story and its likely structures. Inevitably, a student will glibly point out that this movie will have a happy ending, which creates a perfect opportunity to talk about genre and plot. Such questions also help students to create their own schema from their extant story knowledge, although they need guidance, which the maps provide, to see how these disparate factoids fit into an overall pattern. It also creates the opportunity, in both literature and creative writing classes, to discuss alternative choices, to follow a new path thus created from that same node to discuss further possibilities and transformed plots. If she had not accepted his help, for instance, mightn't her son die? Wouldn't this demonstrate how character and choice create plot? We discuss alternative possibilities to see what sort of ending, and therefore, what sort of genre, they might lead to. It can also be shown through concept mapping of both extant and new fiction that each choice can influence future choices, making comic or tragic outcomes more possible, plausible or seemingly inevitable. Finally, it's also a good way to remind creative writing students that one character's entrapment creates more opportunity for interaction, thus producing more fruitful choice/chance plot nodes to enrich their stories.

Nodes can also represent places in the plot where a character's choices are severely limited. Carol, for instance, has reached a point in her life where it is virtually impossible for her to change her socioeconomic status by going back to school, for instance, to earn a college degree. For her, the more plausible possibilities for change must come from outside, i.e. a new element is needed to add choice to her "no-choice" circumstances. Melvin started coming into her coffee shop; Carol had no choice about this. After that first time, even Melvin's choices were severely limited by his OCD (obsessive-compulsive disorder). Such nodes for Carol include not only the accept-or-reject help choices, but also include the "destiny nodes" of Melvin walking into her workplace for food. (See Figure 2.) When Melvin is asked to drive Simon, the artist, to Connecticut for a "big sweaty wad" of his father's cash, this is another destiny/choice node. (Notice, here, that Carol already has some input into his decision, concisely summarizing his "dilemma" as something she'd welcome. "I want your life for five minutes," she tells him, "where my biggest problem is accepting a convertible so I can get out of the city for a week-end.") This, in turn, creates a further choice-node for Carol in considering whether to join them and thus "save" Melvin from Simon's advances. Discussing such intertwining actions and reactions inspires more intricate and more interesting character and plot interactions in the students' own stories.

Alternatively, one can choose a specific scene and adapt the mapping technique to analyze character interplay, such as the three-person dynamic that develops among Carol, Simon and Melvin on their car trip. (By the way, this scene also demonstrates to students that putting two or three people together on a trip is a classic way to create character dynamics.) The characters share life stories and, in discussing such stories, one may introduce more character-driven genres. One may start with the obvious; Melvin and Carol must make their decisions within the framework of a romantic comedy, for instance. One may also discuss Melvin's trajectory as a redemption story and Carol's as a *bildungsroman*, (coming of age story), since she is, after all, young and sensitive and still learning about love and life. While the romantic comedy plot rather limits how characters may behave and what choices we can expect from them, discussion of other plot aspects, such as redemption and *bildungs* stories, can show writing students how to work within a genre, yet still avoid re-hashing one-dimensional clichés. Drawing maps that include elements of all three genres, romantic comedy, *bildungsroman*, and redemption, can help students understand what they have in common and how they differ, and how character traits and plot trajectory interact. For instance, to write their own redemption stories, students will now know that the character to be redeemed, like Melvin, must start out pretty low or there could be no redemption plot - there would be no "upward" for the upward trajectory that redemption stories must trace. One of the most necessary functions of constructivist teaching is disrupting students' simplistic schemas and revealing opportunities to enrich these structures. This allows them to reconstruct that knowledge into more fruitful, more open-minded and more openhearted ways of seeing character and plot; the sheer graphic structure of the maps does that better than a teachers' moral suasion, alone, ever could.

Returning to the plot factor in this story, Melvin's behavior can also demonstrate how a redemption story, to be convincing, must also be gradual. Beginning writing students tend to rush through to the end of the plot, flattening the complexities of human behavior into one, headlong and unconvincing progress. Concept maps using this node method can help them to see human actions and reactions, progress and "backsliding" in a fuller, more satisfying and more convincingly human, conflict-filled picture. Then they can understand that Melvin's wrong moves are as necessary to the plot as the right ones. Each node, furthermore, with its various possibilities for reactions, can free the students' minds from their lock-step progress of oversimplified plots.

For instance, I'll stop the film just after Melvin pays Carol a tremendous compliment (comprised of both self-disclosure, an act of intimacy; and a true compliment, an act of kindness), which is a very right move. Most students have absorbed more story knowledge than they know, as stated previously. This is a good time to let the students demonstrate that to themselves, then translate that knowledge into their "what if" exercise. When I pause the film, then ask the class as a whole, "What will happen now?" someone will always call out, "Now, he'll blow it."

By speculating together in small groups as to how he might do that, students move from reverse engineering to creative writing. In true constructivist-learning mode, fitting this odd bit of simple old knowledge into a concept map helps them to rework their ideas into a more successful creative writing character-plot schema.

3.2 Character Choice – Plot, Action-Reaction Planning with Scaffold Maps

The last in this series of concept maps replaces all the major specifics discussed in *As Good As It Gets* with blank concept boxes for student completion. Using this map can complicate their ready-made, real life, albeit overly simple, characters and incidents into a structurally satisfying story, at once more complex, more structured, and, ironically, more convincing, than reality. Notice that the map attempts to demonstrate the interaction between character and plot, as well as the ongoing network of actions and reactions that a good, character-driven story can create. See Figure 5 below.

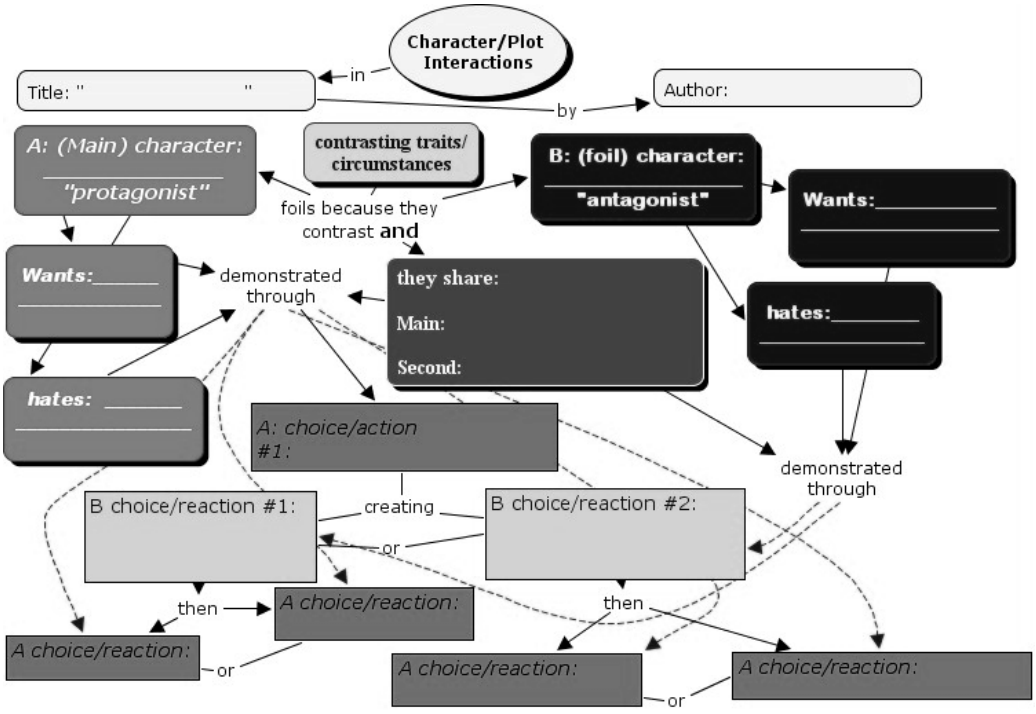


Figure 5. Scaffold map to clarify that plot is a nexus of Character A-action and Character B-reaction nodes

4 Summary

Through practice, my concept maps have evolved from literary analysis through reverse engineering to structures that help students transform their own incidents and "characters" into more complex and more structured stories than they had been writing before. Moving from teacher-generated to student-completed scaffold maps helps students to imagine new characters and new plots. In other words, mapping story structure helps students to refine their half-formed notions about story into structures that gets them "unstuck" from the pure, unadulterated factoids of their lives and into real creativity.

5 Notes

1. The meta-analysis discussed in "Creative concept mapping: From reverse engineering to writing inspiration" includes the results of 211 abstracts revealing an overall 84% approval rating. Of these, almost half (49%) were in the fields of math and science and most of the remaining included real-world, data reduction or other applications. Less than 2% applied the technique to literature or other endeavors requiring writing. None of the abstracts discussed concept mapping in creative writing.

2. Due to space limitations, only a small sample of dissertation abstracts reviewed is included in this list; the entire list is available upon request.

References

August-Brady, Michele M. (2002). The effect of a metacognitive intervention on approach to learning and self-regulation of learning in baccalaureate nursing students. (Doctoral dissertation, Widener University School of Nursing, 2002). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3075171)

Behn, Robin & Twichell, Chase, Eds. (1992). *The practice of poetry*. New York: HarperCollins.

Furniss, Tom & Bath, Michael. (1996). *Reading poetry: An introduction.* London: Prentice Hall.

Harper, Ralph L, Jr. (2001). The professionalization of logistics: A management specialty to meet 21st century challenges. (Doctoral dissertation, Nova Southeastern University, 2001). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3015882)

Hinton, Juliana G. (2000). A narrative study of selected introductory college biology students' struggles to gain an understanding of scale and measurement. (Doctoral dissertation, Louisiana State University and Agricultural & Mechanical College, 2000). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9991749)

Osman-Jouchoux, Rionda. (1997). The use of concept mapping tactics in cognitive strategies for writing summaries of technical material. (Doctoral dissertation, University of Colorado at Denver Graduate School of Public Affairs, 1997). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9804545)

Steele, Ann Marie. (2001). The effect of the length of class time on high school mathematics teaching strategies. (Doctoral dissertation, Temple University, 2000). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3014484)

Straubel, Linda H. (2006). Creative Concept Mapping: From reverse engineering to writing inspiration. Unpublished manuscript.

Sturm, Janet M. (1996). Effects of hand-drawn and computer-generated concept mapping on expository writing and writing attitudes of middle level students with learning and reading disabilities. (Doctoral dissertation, The University of Nebraska, Lincoln, 1996). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9715987)

Williams, Carlos Williams. (1969). Introduction to The Wedge. In *Selected essays of William Carlos Williams.* New York: New Directions, p. 256.

Zea, Kristi. (Producer), & Brooks, James L. (Director). (1997). *As good as it gets.* [Motion picture videocassette]. USA: Sony Pictures.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

CMAPTOOLS FACILITATES ALIGNMENT OF LOCAL CURRICULUM WITH STATE STANDARDS: A CASE STUDY

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Abstract. Concept maps were used to align the Lexington Public Schools' local elementary life science benchmarks and interdisciplinary Big Backyard program with the Commonwealth of Massachusetts (MA) Life Science Framework. *CmapTools* was used to create a template concept map of the MA Life Science Framework. A color-coding system was used to compare life science concepts from the Lexington Elementary Life Science Benchmarks with the state template map. Concepts were color-coded to indicate alignment with the state (green in web version; medium-gray in print version), nonalignment with the state (red in web version; dark gray in print version), and more depth than the state (yellow in web version; light gray in print version). The same method was used to examine how the interdisciplinary Lexington Big Backyard program supports the state's life science framework. The analysis is useful in that it offers a clear visual indicator of "fit" between the state framework and local benchmarks. Its utility comes primarily in assuring that the district addresses the state framework. This alignment strategy offers insight into recommendations that can easily incorporate "red concepts" into existing instructional activities and objectives. As state science testing becomes more high stakes, such alignment methods increase in value. While other alignment strategies exist, concept mapping offers a particularly robust decision-making tool for a constructivist-based learning community. In addition to providing a visual framework, the concept maps, by demonstrating connections among concepts, can help teachers develop instructional activities in a cohesive manner.

1 Background

In the 1980s, the education community at large was put on alert with the release of a number of reports recommending reform in U.S. Education, including: *A Nation at Risk: The Imperative for Education Reform by the National Commission on Excellence in Education.* The science education community responded to these criticisms and 'No Child Left Behind' legislation with national and state standards and benchmarks. Of particular note to the field of science education are the *National Science Education Standards* and the *Benchmarks for Science Literacy: Project 2061*. These publications are the "gold standard" against which many of the state standards and frameworks are judged.

Tremendous efforts have been made to align national-state-local curricula; to align state assessments with the state's curricula; and to align what happens in the classroom with the various levels of curricula. The mission of one independent, not-for-profit organization, Align to Achieve, is to facilitate the evaluation and improvement of academic standards and student achievement. This organization provides a standards database of grades K-12 content standards and benchmarks from states, national organizations and selected countries. With a broader focus, *Science Curriculum Topic Study (SCTS)*, by Page Keeley, bridges the gap between standards and practice. Keeley offers a "methodical study process and a set of tools and strategies– organized around 147 curriculum topics– designed to help educators improve the teaching and learning of science." For each science topic, her book references appropriate sections of key resources that identify the adult content knowledge, instructional implications, concepts and specific ideas, research on student learning, coherency and articulation of the topic, and integration with state standards. SCTS facilitates teachers' efforts to link to the standards and to current research on student learning about different topics.

A variety of "mapping strategies" have been applied to these alignment endeavors. In *Mapping the Big Picture: Integrating Curriculum & Assessment K-12,* Heidi Hayes describes the use of "curriculum mapping" to encourage teachers at the school and district level to map their classroom time and then collaborate to eliminate gaps and repetitions, judge alignment with standards, identify needs for further collaboration and research, and improve their overall spiral delivery of instruction. Each teacher creates a map identifying content, processes, and assessments over the course of the school year.

"Content mapping," on the other hand, is a new analytical method described in *New Tools for Analyzing Teaching, Curriculum and Standards in Mathematics & Science* by Blank, Porter, and Smithson. This very broad study examines links among the intended curriculum, the enacted curriculum, and the learned curriculum (student

outcomes). Content maps are used to represent a two-dimensional matrix showing the amount of time spent on the intersection of content topic (at a general level) and level of expectations for student learning (memorize, understand concepts, perform procedures, conduct experiments, analyze information, apply concepts.) Data collected by this project could be applied to queries about alignment of assessment to assessment; assessment to instruction; and instruction to instruction.

More recent, a collection of "strand maps" was introduced in the *Atlas of Science Literacy*. These maps demonstrate the connections among the national science benchmarks, which are listed sequentially in the *Benchmarks for Science Literacy*. Clusters of large maps integrating clusters of benchmarks indicate connections of benchmarks from K-2 to 3-5 to 6-8 to 9-12 levels. The *Atlas* clearly illustrates the importance of prior knowledge upon which each succeeding level of instruction builds as well as the rich fabric of interconnections among different clusters of related maps. The *Atlas* connects both content knowledge and process knowledge. The goal of the Atlas is that "thinking carefully about the growth of understanding from kindergarten to graduation is an essential part of planning what students can be expected to learn and how best they can be helped to do so." The mission of integrating sequenced benchmarks into connected understandings touches on the strengths of Novak's concept mapping process, which is used in this case study.

2 Introduction

In the last few years, the statewide assessment in Massachusetts has emphasized English language and mathematics. Now, as science testing becomes more high stakes (i.e., required for high school graduation in the Class of 2010), schools are working to align their local science curriculum with the state's science framework. While prior work demonstrates the application of concept mapping to teaching and learning in the sciences (Cañas, et al. 2004b; Mintzes, et al. 1997; Novak 1998), this case study explores the utility of using concept maps to align a local life science curriculum with the state life science framework.

In Massachusetts, the Science and Technology/Engineering Curriculum Framework, was published by the Massachusetts Department of Education in 2001. The Science Framework addresses both science inquiry processes and conceptual content. The Massachusetts Comprehensive Assessment System (MCAS) primarily addresses conceptual content. Framework revisions are currently being incorporated. The full document is available in pdf format at http://www.doe.mass.edu/frameworks/scitech/2001/0501.pdf. State frameworks for all disciplines are available at http://www.doe.mass.edu/frameworks/current.html.

Individual school districts, as is the case with the Lexington Public Schools, often operate from local curriculum guidelines. The Lexington Elementary Science Benchmarks (Lexington Benchmarks) describe the overall goals and objectives of the entire science program. (The Lexington Public Schools curriculum is available at http://lps.lexingtonma.org/curriculum/elementary.html.) These goals include conceptual content from the life sciences, earth sciences, and physical sciences, as well as inquiry skills.

Some of these Lexington Benchmarks are addressed by the interdisciplinary Lexington Big Backyard (BBY) program. This program of seasonal walks on the schoolyard and adjacent conservation lands, led by trained parent volunteers, has developed over the course of a decade. It was designed to address both science and social studies goals. Objectives for the walks address not only appropriate content in the life sciences, earth sciences, physical sciences, and social sciences, but also science inquiry processes, affective goals (such as environmental awareness and attitudes of respect toward the environment and each other) and psychomotor goals (such as the use of appropriate science equipment). Developed before and then simultaneously with the state frameworks, some effort has been made to align the BBY program with the state science and history and social science frameworks.

While a variety of methods to align curricula have been used, concept mapping offers the potential of integrating the concepts into a visual conceptual structure highlighting connections among concepts. This case study limits itself to demonstrating alignment of the district's life science content specified in both the Lexington Benchmarks and BBY program with the state life science framework. It does not investigate the enactment of the district curriculum in the classroom, the level of student performance expected with the content, or developmental level of the content. However, it has the potential to demonstrate integration and connections among concepts at a more detailed level than was carried out by other alignment studies. It may be relatively easy for a district to

incorporate “red concepts” into their benchmarks that address the alignment map’s adjacent “green-coded” concepts. Hence, at a detail level, the connectivity facilitates recommendations for areas of omission that the district may wish to address. It also clarifies areas that the state framework does not address at this point in time. This effort will help further the Lexington Public Schools’ goal of aligning curricula more closely with the state frameworks.

2 Method

Steps taken to examine alignment of curricula with the science framework involved the following transformations:

1. A state concept list, retaining as much of the explicit and implied propositional linkages and hierarchy as possible, was derived from the Massachusetts Elementary Life Science Framework. The Massachusetts science standards are listed in a table format indicating learning standards, ideas for developing investigations and learning experiences, and suggestions for extensions to learning in technology/engineering. The life science framework is divided into conceptual clusters. The clusters of Grades PreK-2 standards (pp.39-40) include characteristics of living things, heredity, evolution and biodiversity, and living things and their environment. The clusters of Grades 3-5 standards (pp. 41-44) include characteristics of plants and animals, plant structures and functions, adaptations of living things, and energy and living things.

2. Using *CmapTools* (Cañas et al., 2004a), the state concept list was used to create a template framework concept map. The template map includes a core map (Figure 1) and three submaps, which can be viewed by clicking on the attachment icons for three of the concepts: ‘Living Things,’ ‘Food Chains,’ and ‘Plants.’ (http://cursa.ihmc.us:80/servlet/SBReadResourceServlet?rid=1143727786182_1913844725_6339&partName=htmltext) To view the state concept list, one can click the icon at the bottom of the ‘Environment’ concept.

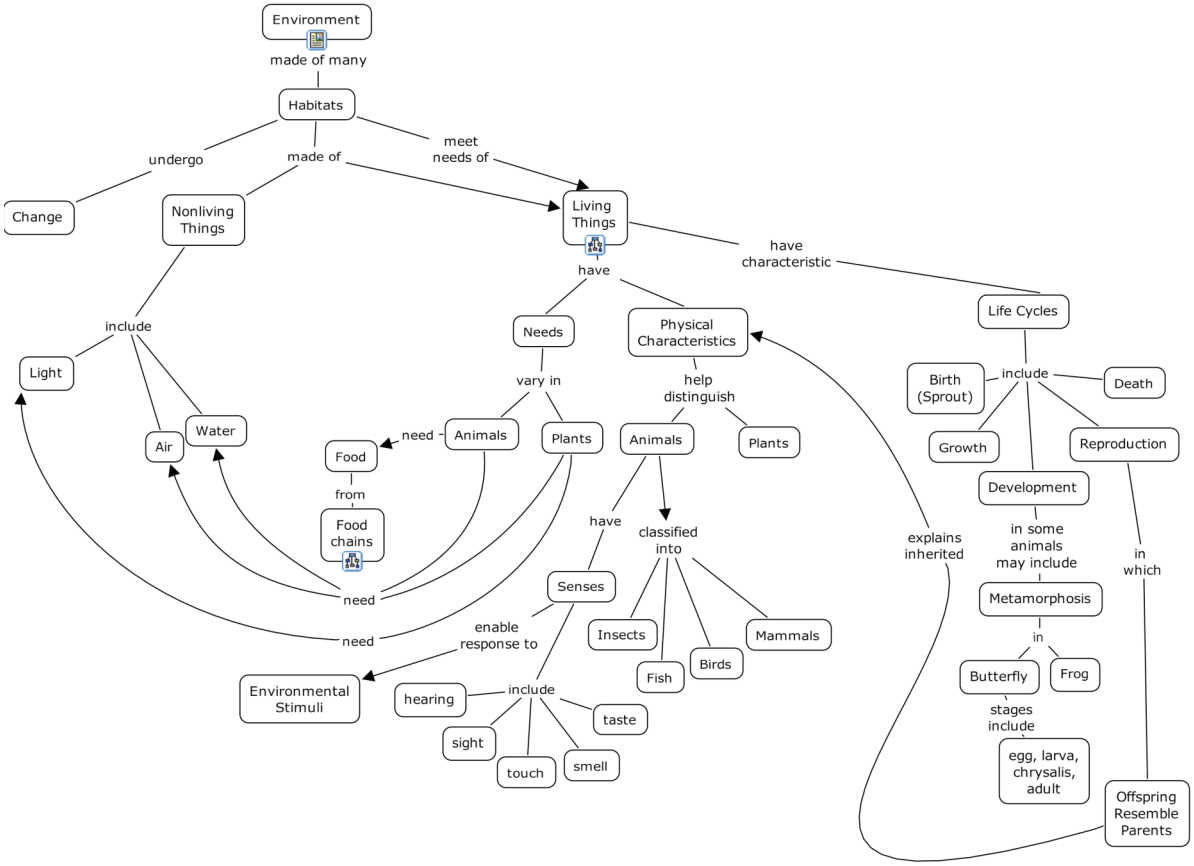


Figure 1. Massachusetts Framework ‘Core’ Concept Map

3. A local curriculum concept list was derived from the Lexington Benchmarks.

4. Concepts on the state template concept map were color-coded: 'green' in the web version (medium-gray in the print version) for concepts found in both the framework and the local benchmarks; 'red' in the web version (dark-gray in the print version) for concepts found in the framework, but not the local benchmarks; 'yellow' in the web version (light-gray in the print version) for concepts found in the local benchmarks, but not in the framework. For the gray tones in the print version of "Core Map", see Figure 2. This alignment can be viewed in color and with submaps on the web at: http://cursa.ihmc.us:80/servlet/SBReadResourceServlet?rid=1143727786182_1874593061_6336&partName=htmltext. To view the Lexington Benchmarks concept list, one can click the icon at the bottom of the 'Environment' concept.

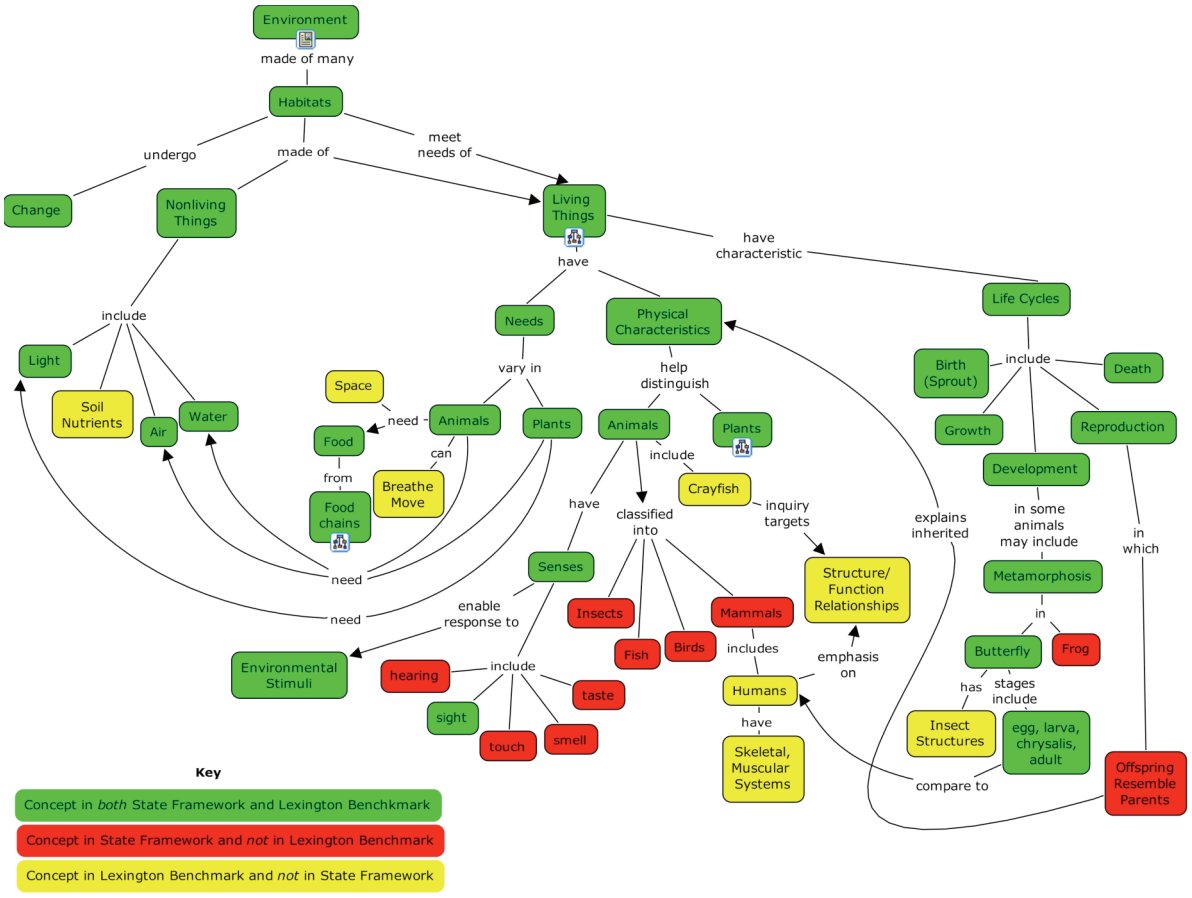


Figure 2. 'Core' Concept Map Aligning Lexington Benchmarks with State Framework

5. A Big Backyard concept list was derived from the stated objectives of the original printed handouts of the K-5 walks and the objectives listed in the "Grade Overview" and "Teacher" documents available at the Big Backyard website.

6. Concepts on the state template concept map were color-coded with the same strategy as the Lexington Benchmarks. (See "4" above.) Note, this map has an additional submap located by clicking on the "Habitat" concept. This alignment can be viewed in color and with submaps on the web at: http://cursa.ihmc.us:80/servlet/SBReadResourceServlet?rid=1143727786182_1921903453_6343&partName=htmltext. To view the BBY concept list, one can click the icon at the bottom of the 'Environment' concept.

For an alternative route to observe the alignment concept maps on the web, go to [http://cursa.ihmc.us/]. Then open the folder titled " JHFry CMaps, MA" (Scroll down. . . It's in alphabetical order.) Then open " 1 Elementary

School", then "MA Elem Life Sci Framework". Select the concept map titled " Lex Life Science Framework K-5." (Repeat for the Benchmarks and BBY folders.)

3 Results

3.1 State Template Map and General Alignment Results

The core template map created with *CmapTools* underwent three revisions. With each revision, the map's focus and the connections among concepts were clarified. The core map is primarily the K-2 concepts. It emphasizes habitats made of both living and nonliving things together with their interactions and life cycles. There is some repetition of concepts going to submaps in order to show some connections among concepts. The "Living Things" submap emphasizes characteristics of living things, both physical and behavioral, which aid in adaptation to the environment and its changes. The "Food Chains" submap covers key ecological concepts related to food. The "Plants" submap addresses plant structure and function.

What do the alignment maps of the Lexington Benchmarks and Big Backyard program tell us about the Lexington elementary life science curriculum? A table summarizing number of concepts offers some insights. Note that the precision of counting numbers of colored concepts can be somewhat skewed. Why? Some concepts are just examples, so are not really as powerful as key concepts themselves. Therefore, they carry a bit too much weight. (This is particularly the case in the "Living Things" submap.) On the other hand, some concepts are clustered together because of map size limitations; therefore, these concepts may carry less weight. (Note "egg, larva, chrysalis, adult" in the core map.) In spite of these caveats, some patterns emerge. Examination of the overall alignment map of the Lexington Benchmarks reveals almost 2/3 alignment to the standards. A closer examination shows that core map with 75% alignment and the food chains submap with 92%, while the other two submaps indicate less than 50% alignment ("Living Things" at 42% and "Plants" at 47%). (See Table 1.) What does closer examination of the maps reveal?

Benchmark Alignment Map	Number of Green Concepts (G) [in state and in local]	Number of Red Concepts (R) [in state, not in local]	Number of Yellow Concepts (Y) [in local, not in state]	% Alignment [G/ (G+R)] X 100
Core	30	10	9	75
Living Things	13	18	1	42
Food Chains	12	1	3	92
Plants	7	8	5	47
Total	62	37	18	62

Table 1. Analysis of Alignment of Lexington Benchmark Concepts with State Framework Concepts.

3.2 Core Map Alignment Results

Lexington addresses ¾ of the framework concepts: life cycles and the needs of living things being met by habitats in which they live. There are, however, three key "red zones" where the Lexington Benchmarks are missing concepts stated in the standards: the senses, major animal classification groups, and a basic understanding of heredity. Concepts of the "senses" are of little concern because they are implied in the inquiry section of the Lexington Benchmarks and explicit in the Big Backyard objectives. One exception is the sense of "taste," because elementary students are discouraged from tasting outdoor samples! (See the BBY core alignment map.) "Yellow zones" indicate that Lexington emphasizes relating structure and function in living systems: insect structures in the butterfly life cycle study; skeletal and muscular systems in the human body; crayfish in behavior studies.

While students in the Big Backyard program are exposed to a tremendous variety of organisms in the four indicated habitats, the focus is on discussion of how the organisms are adapted for the habitat in which they are found. Classification of organisms into major animal groups is not explicit in either the Lexington Benchmarks or the Big Backyard program. On the other hand, students in Big Backyard activities do experience identification of common trees, plants in the wetlands, and aquatic organisms of the stream. The framework appears, however, to

target student conceptual understanding of how to use dichotomous keys in classifying the major animal groups: insects, fish, birds, and mammals. From the "red zone," it is clear that the Big Backyard program does not address the life cycle part of the map. However, from the Lexington Benchmarks alignment maps, we can deduce that those concepts are addressed by "inside activities" at Lexington.

3.3 Submap Alignment Results: Living Things, Plants, Food Chains, Habitats

The "red space" on the Lexington Benchmarks 'Living Things' submap is glaring: alignment of Lexington's curriculum with the state standards is only 42%. In addition to the state framework's strong articulation of "adaptations of behaviors and physical characteristics," there is an additional subordinate conceptual layer that distinguishes "learned and acquired characteristics" from "inherited characteristics." This is a "red zone" for Lexington, exacerbated by the number of examples provided in the framework. An examination of the BBY 'Living Things' alignment submap indicates an emphasis on the relationship of seasonal adaptations to seasonal changes. BBY, however, does not address the difference between learned behaviors and instincts nor between inherited and environment-influenced physical characteristics.

With only 47% alignment on the 'Plants' submap, it is clear that something is missing in the Lexington Benchmarks. An examination of the map offers two insights. The "red zones" indicate that the Lexington Benchmarks address plants' structures, but not functions. This observation is surprising, since the Lexington Benchmarks are so strong in connecting structure and function in other conceptual areas mentioned previously. On the other hand, "yellow zones" indicate that Lexington's approach to plants is stronger in viewing plants as part of a larger system. Its strength is in ecologically connecting plants to the nonliving parts of the environment through soil needs and in the role played by worms. The BBY alignment map reinforces the Lexington Benchmarks map in addressing plant structure, but not function. The Lexington curriculum adds "seeds" to plant structure concepts.

With 92% alignment on the 'Food Chains' submap, it is clear that Lexington Benchmarks excel in food chain concepts. A closer look indicates that the only missing "concept" is the "label" of photosynthesis. (This label is included in the BBY map). Lexington Benchmarks offer one more superordinate concept (food web) and two more subordinate concepts (primary consumer, secondary consumer) beyond the state standards. Food chains are clearly covered by the BBY program. Again, the linkage of decomposers back to the nonliving components of the ecosystem is a clear connection made in this program. Further, the BBY program so strongly addresses habitats, that an additional 'Habitats' submap was created. BBY visits a variety of habitats, including field, forest, wetland, and stream. Structure and function of the wetland are targeted concepts. The stream habitat details identification of living aquatic organisms as well as nonliving qualities of the habitat: pH, color, cloudiness, and odor.

4 Conclusions

Concepts from the state science framework can be transformed into a template concept map. Color-coding of concept maps visually clarifies alignment of school content with the framework. While interpretation of individual concepts and propositional linkages are in some cases subjective, this analysis clarifies larger patterns of alignment areas, nonalignment areas, and extensive depth beyond the state framework. The detailed concept mapping work offers strength in examining the integration of the conceptual content of a subject. When used to examine alignment between district benchmarks and state framework, the connectivity of a concept map suggests where missing elements may easily be added.

5 Recommendations

Based upon these findings, both specific and broad recommendations can be made.

5.1 Specific recommendations

Depending upon school policy, the science coordinator could work to increase alignment of the local curriculum to the state framework. Assuming closer alignment is desired, content areas coded 'green' should remain in the local curriculum. In general, educators should consider the green-coded concepts as "core" and strive for high

performance by all students in attaining them. The curriculum coordinator should work to incorporate content areas coded 'red' into the local benchmarks. Areas that call for more emphasis or clarity include: classification of major animal groups; basic inheritance understanding that offspring resemble their parents and that inheritance gives rise to observable physical characteristics; clarification of learned and acquired adaptations vs instinctual and inherited adaptations; plant adaptations to light and gravity; and sensory systems. The recommendations do not generally call for a redesign of approach. Sometimes this means simply adding content which is already in the enacted curriculum, but has not been emphasized in the Lexington Benchmarks document. Sometimes it means simple alteration of objectives in some of the Big Backyard walks. The concepts coded 'yellow' can be considered strengths of the school system and areas of depth or extension. Yellow-coded concepts could be considered "nice to know, but not necessary." This coding should be of particular significance to special needs teachers working with students who struggle with the amount of material they are expected to learn.

The Massachusetts Department of Education (DOE) might also take note of this analysis. Although 'seeds' are implied in an understanding of life cycles, 'seeds' might be added to the list of plant structures in the framework. While the framework emphasizes the relationship of structure and function in plants, it does not do so for animals. A problem in the elementary science framework (p. 41) is that some standards relating to animals are listed under the 'Plant Structures and Functions' subheading. One way to solve the problem would be to create a new subheading titled 'Animal Structures and Functions.' Standard 3 regarding "life cycles of plants and animals" could move to the 'Characteristics of Plants and Animals' subheading. Standard 4 relating to metamorphosis in animals could shift to the new 'Animal Structure and Function' subheading. Finally, while the state framework emphasizes the "flow of energy through an ecosystem," the DOE might consider addressing the "cycling of matter," which is so clearly emphasized in the Lexington curriculum. With many Massachusetts schools involved in recycling projects, this change seems appropriate. Further, "thinking in systems" is crucial to the study of all scientific disciplines.

5.2 Extension of Concept Mapping Alignment Function

Alignment analyses could be extended to more types of concepts, levels of the educational system, school leaders, and disciplines. In addition to content standards, science *process* concepts could be aligned. Such an analysis would balance the tendency of the state frameworks to emphasize content standards. Alignment maps carried out at the elementary, middle school, and high school levels would inform an entire school system about their alignment with state standards. They would also give teachers at each level insights about the "prior knowledge" of their students upon which they would build. Such a process would move in synchronous steps with the *Atlas* and *SCTS*.

Alignment maps could be used in a number of ways by the science coordinator to more fully integrate the educational system. Sharing these alignment maps with teachers and volunteer parents demonstrates how their efforts in individual activities contribute to the development of a larger integrated "whole" for their learners. Linking digitized activities to the alignment maps would facilitate that process, as would indicating grade level for each of the concept areas. Individual teachers could align their particular class with local or state curricula to see how their classroom work supports systemic priorities. This type of work would support efforts by the *Survey of the Enacted Curriculum Project*.

In addition to life sciences, other sciences and other disciplines could be aligned. Schools that emphasize thematic learning and integrated disciplines might find the more extensive analysis and synthesis to be a useful tool. The field of environmental education emphasizes interdisciplinary relationships. The North American Association for Environmental Education (NAAEE) recently published *Guidelines for Excellence K-12*. As with the MA life science framework, template concept maps of the conceptual goals for the *Guidelines for Excellence* could be used by environmental education programs to evaluate their "fit" with the national standards.

5.3 Beyond Curriculum Alignment

As connections among the science concepts become clearer at a curricular level, it makes sense to have students create their own maps as they experience both indoor and outdoor science activities. Individual portfolios can serve as MCAS review at the end of the fifth grade. This is an easy step at Lexington, where students already use *Inspiration* software.

Concept mapping, based upon Ausubelian learning theory (Ausubel, et al., 1978), offers a clear opportunity for teachers to build upon students' prior knowledge. When curriculum coordinators offer the vision of linkage between connected conceptual knowledge and classroom instruction and when students construct knowledge while connecting their emerging conceptual structure to their own observations, experiences and research findings, then each succeeding level of education is empowered to offer a truly integrated educational experience.

6 References

Align to Achieve. This organization provides information about content and skill level across the four major disciplines K-12 for all the state frameworks. http://www.aligntoachieve.org/

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy: Project 2061*. Oxford University Press: New York.

Atlas of Science Literacy: Project 2061. (2001). American Association for the Advancement of Science and the National Science Teachers Association: Washington, DC.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). *Educational Psychology: A Cognitive View, Second Edition*. New York, N. Y.: Holt, Rinehart, and Winston.

Blank, R. K., Porter, A., Smithson, J. (2001). *New Tools for Analyzing Teaching, Curriculum and Standards in Mathematics & Science. Results from Survey of Enacted Curriculum Project*. Final Report. Council of Chief State School Officers, ATTN: Publications, One Massachusetts Avenue, NW, Suite 700, Washington, DC 20001-1431. (Available in pdf format at http://eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/0d/8c/5a.pdf)

Cañas, A.J., Hill,G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gomez, G., Arroyo, M., & Carvajal, R. (2004a). *CmapTools*: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), *Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping.* Pamplona, Spain: Universidad Publica de Navarra.

Cañas, A. J., J. D. Novak & F. M. Gonzalez (Eds.). (2004b). *Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping, Volumes 1 and 2*. Pamplona, Spain: Universidad Publica de Navarra.

Gardner, David Pierpont. (1983). *A Nation at Risk: The Imperative for Educational Reform*. A Report to the Nation and the Secretary of Education, United States Department of Education by the National Commission on Excellence in Education. Washington, D.C.

Heinze-Fry, J. A. (2004). Applications of Concept Mapping to Undergraduate General Education Science Courses. In A. J. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), *Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping.* Pamplona, Spain: Universidad Publica de Navarra.

Jacobs, H. H. (1997). *Mapping the Big Picture. Integrating Curriculum & Assessment K-12.* Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314-1453.

Keeley, P. (2005). *Science Curriculum Topic Study.* Corwin Press: Thousand Oaks, CA.

Massachusetts Department of Education. (2001). *Massachusetts Science and Technology/Engineering Curriculum Framework.* (Available online at www.doe.mass.edu/frameworks/current.html.)

Mintzes, J. J., Wandersee, J. H., & Novak, J. D., eds. (1997). *Teaching Science for Understanding: A Human Constructivist View*. San Diego, CA: Academic Press.

National Research Council. (1996). *National Science Education Standards,* Ninth Printing. National Academy Press: 2101 Constitution Avenue NW, Box 285, Washington, DC 20055.

North American Association for Environmental Education. (1999). *Excellence in Environmental Education—Guidelines for Learning (K-12)*. 1825 Connecticut Avenue NW, 8th Floor, Washington, DC 20009-5708

Novak, J. D. & Gowin, D. B. (1984). *Learning How to Learn*. Cambridge: Cambridge University Press.

Novak, J. D. (1998). *Learning, Creating, and Using Knowledge: Concept Maps ™ as Facilitative Tools in Schools and Corporations*. Mahwah, NJ: Lawrence Erlbaum Associates.

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COLLABORATIVE CONCEPT MAPPING IN EDUCATION: MAJOR RESEARCH TRENDS

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Abstract. Since the late eighties, more and more researchers have been exploring the potential of collaborative concept mapping to support learning. In those studies, students construct concept maps in pairs or in small groups. This paper presents a review of research trends on collaborative concept mapping in education. We present an overview of the theoretical framework, methodology and main results of 39 published studies investigating this topic.

1 Introduction

In the last decade, the socioconstructivist paradigm has become increasingly predominant in education, where collaborative learning is considered as being beneficial to learning. Since the late eighties, some researchers have been exploring the potential of collaborative concept mapping (CCM) to support learning. In those studies, students construct concept maps in small groups. With the development of concept mapping (CM) software and web-based technologies, CCM, either at a distance or in a face-to-face condition, has become even more popular. Thus, research on CCM has thrived in the last years. However, reviews of research on CM in education (e.g. Horton *et al*., 1993; Nesbit & Adesope, submitted) do not specifically address issues related to the collaborative context of the CM activity in some studies. This paper presents trends from a review of 39 published studies on CCM. Those studies were found using *ERIC*, *FirstSearch,* and *PsychFirst* databases. The proceedings of the *CMC 2004 Proceedings* were also searched. An overview of the CCM studies found is presented in Table 1. Only one study has been conducted before the nineties, 12 in the nineties, and 26 since 2000. This confirms that research on CCM has intensified in the last years.

2 Theoretical framework and research methods of studies on collaborative concept mapping

Fourteen studies did not specify a theoretical framework related to the collaborative nature of their research. Sociocultural learning (e.g. Vygotsky, 1978), symbolic interactionism (e.g. Mead, 1934/1974), sociocognitive conflict theory (Mugny, Perret-Clermont, & Doise, 1981), and situated learning (e.g. Rogoff & Lave, 1984) frameworks are mentioned in 6 to 8 studies in each case. Four studies refer to the collaborative learning literature (e.g. Slavin, 1990; Deutsch, 1949). Distributed cognition (e.g. Salomon, 1993) appeared in some studies after the year 2000. Other theoretical frameworks (teamwork and relational cognition) are mentioned in three studies.

Research methods used by CCM researchers are mostly experimental (21). Non-experimental methods (action research, qualitative research, etc.) were also quite popular (15), especially those investigating social interactions during CCM. Only three studies used quasi-experimental methods, (with non-randomized samples). The majority of studies (22) had less than 50 participants with a range from 15 to 808 and a mean of 76 (see Table 1). Twenty-five studies were done with students in higher education and 14 were done with students in grade school. Of the 39 studies, the Sciences were used most often as CM topic (24). Education came in a close second with 12. Thirty studies created teams of two or three. Twenty-two studies used some grouping criteria (gender, ability, familiarity, etc.). In two cases, the CCMaps were produced by the class as a whole. In most of the studies (28), participants used digital CM tools. Nine used non-digital tools and two used both. Four studies do not specify what tool was used (probably paper-and-pencil). Sixteen studies specified that communication during CCM was done face-to-face. Digital tools were used for communication in 19 studies and 13 of those used chat. Nine studies specified some communication constraints. In seven cases, predefined roles were imposed (e.g. leader, explainer, advisor, etc.), four of them being rotating roles. Predefined messages were used in 6 cases (complete messages or message stems). During the CM task, 16 studies used predefined nodes, four predefined node types, 11 predefined links, four predefined link types, and nine used other constraints. These conditions are not mutually exclusive (see Table 1). It is difficult to determine the duration of the studies because, although they may explicitly state their time frame, we cannot identify how long students spent constructing CCMaps. In seventeen studies, participants created a CCMap in one session lasting from 36 to 120 minutes. The same number of studies based their analysis on multiple CCM sessions, with a wide range from one week to one year. In those cases, we do not have the exact time students actually spent on the CCM task. Five studies did not specify the duration of the CCM task at all.

Table 1 – Studies on Collaborative Concept Mapping[1]

Authors & Year	Participants & Topic	Grps	CM Tool	Compared groups	CM Task	Comm. Tool
(Okebukola & Jegede, 1988)	145 HE Biol.	5	ND	CCM, ICM, OIA	-	F2F
(Okebukola, 1992)	60 HE Biol.	5	ND	CCM, ICM, OIA	F	F2F
(W.-M. Roth & Roychoudhury, 1992; W. Roth & Roychoudhury, 1993)	148 HE Physics	3-4	ND	CCM	PN	F2F
(Esiobu & Soyibo, 1995)	808 S Biol.	5	ND	CCM Coop, CCM Coop-comp, ICM, OCA Coop, OCA Coop-comp, OIA	F	F2F
(Reinhard, Hesse, Hron, & Picard, 1997)	60 HE Biol.	2	D	All CCM: Manipulable graphics, Static graphics	Other	Chat
(Sizmur & Osborne, 1997)	84 P Sciences	-	ND	CCM	PN	F2F
(van Boxtel, van der Linden, & Kanselaar, 1997, 2000)	40 S Sciences	3	ND	CCM (w/ individual preparation) CCM (w/o individual preparation) OCA (w/ individual preparation) OCA (w/o individual preparation)	PN	F2F
(Coleman, 1998)	48 P Biol.	3	ND	All CCM: High intentional learners (w/o prompt), Average intentional learners (w/prompt), Average intentional control (w/o prompt)	PN PL	F2F
(Czerniak & Haney, 1998)	118 HE Sciences	Class	D (PIVIT)	CCM, OIA	F	F2F
(Chung, O'Neil, & Herl, 1999) (Pilot Study)	30 S Envir. Sc.	3	D	CCM	PN PL	Chat
(Chung, O'Neil, & Herl, 1999) (Main Study); (Herl, O'Neil, Chung, & Schachter, 1999)	111 S Envir. Sc.	3	D	CCM	PN PL	Chat
(Osmundson, Chung, Herl, & Klein, 1999)	52 P Biol.	3-4	D	CCM, OCA	PN PL	Chat
(van Boxtel & Veerman, 2001)	20 S Educ.	2 -3	D (Belvedere)	CCM	PN PL	Chat
(Chiu, Huang, & Chang, 2000)	36 HE Comp.HW	3	D	CCM	PN PL	Chat
(Chiu, Wu, & Huang, 2000)	30 P Comp. HW	3	D	CCM	PN PL	Chat
(Fischer & Mandl, 2000)	48 HE Educ.	3	ND D (CoStructure)	All CCM: F2F Domain-Specific Tool, F2F Domain-Unspecific, Online Domain-Specific, Online Domain-Unspecific	PL Other	Video-conf.
(De Simone, Schmid, & McEven, 2001)	26 HE Ed.Tech.	3-5	D (PIVIT, Inspiration)	CCM	F	F2F (forum not used)
(Fischer & Mandl, 2001, , 2002)	64 HE Educ.	3	ND D (CoStructure)	All CCM: F2F Domain-Specific Tool, F2F Domain-Unspecific, Online Domain-Specific, Online Domain-Unspecific	PL Other	F2F Video-conf
(Kealy, 2001)	13 HE Educ.	2- 3	D (Inspiration)	CCM	PN	F2F
(Suthers & Hundhausen, 2001)	60 HE Sciences	2	D (Belvedere)	CCM, OCA (Matrix), OCA (Text)	PNT PLT	F2F

[1] Legend:
Participants: **H**igher **E**ducation; **S**econdary; **P**rimary.
CM Tools: **D**igital; **N**on-**D**igital.
Compared Groups: **C**ollaborative **C**oncept **M**ap; **I**ndividual **C**oncept **M**ap ; **O**ther **C**ollaborative **A**ctivity; **O**ther **I**ndividual **A**ctivity.
CM Task: **F**reestyle; **P**redefined **N**odes; **P**redefined **L**inks; **P**redefined **N**ode **T**ypes; **P**redefined **L**ink **T**ypes.

Authors & Year	Participants & Topic	Grps	CM Tool	Compared groups	CM Task	Comm. Tool
(Fischer, Bruhn, Gräsel, & Mandl, 2002)	32 HE Ed.Psych.	2	D (CoStructure)	All CM: Domain-Specific Representation Tool, Domain-Unspecific Representation Tool	PL Other	F2F
(Gilbert & Greene, 2001-2002)	15 HE Ed.Tech.	3	D (Inspiration)	CCM	PN Other	F2F
(Komis, Avouris, & Fidas, 2002)	17 HE Computing	2	D (Representation	CCM	-	Chat
(Stoyanova & Kommers, 2002)	36 HE Ed. Tech.	4-5	D (Inspiration)	ICM Distributed mapping (shared ICM), ICM-Moderated mapping mode (Shared ICM adjusted by moderator), CCM-Shared mapping mode (synch), OCA (outline)	F	F2F
(Suthers, Girardeau, & Hundhausen, 2002)	20 HE Sciences	2	D (Belvedere)	All CCM: F2F, Distance	PNT PLT	F2F, Chat (distance group)
(Chang, Sung, & Lee, 2003) (Study 1)	17 HE Hist.	2– 3	D	CCM	F	Chat
(Chang, Sung, & Lee, 2003) (Study 2)	23 HE Educ.	3-4	D	CCM	F	Chat
(Ledger, 2003)	226 S Astron.	2-3	ND	CCM, OIA	-	F2F
(Suthers, Girardeau, & Hundhausen, 2003)	40 HE Sciences	2	D (Belvedere)	All CCM: F2F, Distance	PNT PLT	F2F, Chat
(Basque & Pudelko, 2004)	48 HE Ed. Tech.	2	D (MOT)	All CCM: Email, Chat, F2F	PNT PLT	Chat, Email F2F
(Chiu, 2004)	96 P Sciences	3	D	All CCM: Assign, Rotate, Give, Open	PN PL	Chat
(Depover, Quintin, & De Lièvre, 2004)	18 HE Educ.	2	D	All CCM: Contrasted pairing based on previous ICM, Self-selected	PN	Forum
(Karasavvidis, 2004)	54 P Hist.	2-3	D (Inspiration)	CCM	-	F2F
(Khamesan & Hammond, 2004)	30 HE Web Design	2	D (Cmap)	All CCM: F2F, Online w/chat, Online w/audio and chat	F	F2F Chat Audio
(Liu, 2004)	15 S Chem.	2	D (Inspiration)	CCM	-	F2F
(Silander, Sutinen, & Tarhio, 2004)	20 P Biol.	Class	D (MoCoCoMa)	CCM	F	Chat, SMS
(Khamesan & Hammond, 2005)	60 HE Web Design	2	D (Cmap)	All CCM: Web-based Shared Interaction, Web-based moderated interaction (Assign 1 member as editor), Non web-based distributed interaction (rotate each 10 min.)	F	Chat + audio
(Kinchin, De-Leij, & Hay, 2005)	150-180 HE Biol.	5	ND	CCM	PN	F2F
(Lee & Nelson, 2005)	44 HE Ed.Tech.	2	D (Inspiration)	All CCM: High K/Generative CM, High K/Completed Map, Low K- Generative Map, Low K/ Completed map	PN	F2F

3 Results of the studies on collaborative concept mapping

The issue of the ***effect of CCM on task performance*** (quality of the CCMaps) had been investigated in 19 studies. Some researchers explored this issue from a developmental perspective (Kealy, 2001; Karasavvidis, 2004; Liu, 2004). In 10 cases, the CMaps were analyzed with a qualitative scheme. Two studies show that CCMaps are better scored than individual CMaps (Okebukola & Jegede, 1988; Czernizk & Haney, 1998). Other researchers examined the effect of varied conditions of CCM on task performance. For example, Coleman (1998) found that "average intentional learners" performed better than their counterparts at CCM tasks if they are prompted, and similarly to "high intentional learners" who are not prompted. Fisher *et al.* (2002) found that the use of a content-specific computer-based CM tool results in better CCM performance than a content-unspecific one. Stoyanova et Kommers (2002) found that a "shared" mapping mode (synchronous CCM) results in better performance compared to a distributed mode (shared individual CMaps until a common vision is attained) and a "moderated" mode (shared

individual CMaps adjusted by a moderator). Chiu (2004) found that performance is lower when roles are rotated than when they are assigned, given, or left open. In another study, groups of students of mixed individual CM ability did not produce better CCMaps than self-selected groupings (Depover, Quintin & De Lièvre, 2004). Three studies compared task CCM performance in a face-to-face (F2F) context and in a distance one. Basque & Pudelko (2004) found that the performance in a F2F condition is better than in an asynchronous one (email). When a F2F condition is compared to a synchronous one (chat with or without audio), no significant difference was found in group achievement in the Khamesan & Hammond studies (2004; 2005).

The ***effects of CCM on learning***, as measured by post-CCM measures (achievement test, problem-solving test, comprehension test, individual CMaps produced after the collaborative CM activity, etc.), are investigated in 22 studies. Compared to individual CM or to other types of collaborative activities (e.g. producing an outline or a matrix representation) CCM has been found to be more beneficial for learning (Okebukola & Jegede, 1988; Eseiobu & Soyibu, 1995; Czeniak & Haney, 1998; Osmundson *et al*., 1999; Stoyanova & Kommers, 2002; Ledger, 2003). However, we also found some "no-significant-difference" studies (Okebulola, 1992; van Boxtel *et al*., 1997, 2000; Suthers & Hundhausen, 2001). Other researchers explored the differential effect of varied CCM conditions on learning. For example, Reinhardt & al. (1997) found that using a manipulable graphical CCM tool lead to better learning than using a static graphical version of the tool during a problem solving post-test. Suthers, Girardeau & Hundhausen (2003) observed no significant difference between F2F and distance groups in a memory-based post-test, but F2F groups performed better on written essays produced after the CCM activity (Suthers, Girardeau & Hundhausen, 2003). Findings of Fischer & Mandl (2000; 2001; 2002) did not show any impact of different communication modes (F2F *vs* online) and tools (domain-specific *vs* domain-unspecific) on knowledge construction. Similarly, Basque & Pudelko (2004) did not observe a difference in comprehension post-test between groups using F2F or distance mode of communication (chat or email) during a CCM activity. Khamesan & Hammond (2004) obtained similar results with post-test individual CM comparing F2F and synchronous distance conditions (chat with or without audio). In a subsequent study, however, they found that a "non web-based distributed interaction" (one student working on the CMap during ten minutes and then passing it on to his partner, without visualizing each others' processes) lead to higher "knowledge acquisition" than synchronous ones. Knowledge acquisition was measured by calculating the total number of new concepts included in the post-individual CMap compared to the pre-individual CMap. However, there was no statistical significant difference among the conditions in means of participants' individual creativity and retention. Chiu (2004) found that triads with assigned roles using a web-based CM system with built-in predefined messages obtained higher scores on post individual CM compared to triads with rotating roles (every three minutes). Finally, Lee & Nelson (2005) found that groups which generated CCMaps performed better at problem-solving than groups which simply completed CCMaps.

Approximately half of the studies investigated the ***interactions between students during CCM***. Roth & Roychoudhury (1992, 1993) are among the first researchers to study this issue. Using qualitative research methods, they observed sustained science discourse during CCM in junior and senior physics classes, and that this discourse replicates the typical interactions in scientific communities, that is, co-construction interactions, adversarial interactions and formation of alliances. Sizmur & Osborne (1997) also observed "the phenomenon of children's continuing each other's contributions" during CCM, which allowed participants to make more scientifically valid propositions than non elaborated exchanges. van Boxtel *et al.* (2000) observed a larger quantity of elaborated cognitive conflicts and of constructed reasoning episodes between pairs creating a CCMap than those who created posters. However, in the Chang, Sung & Lee (2003) study, adult participants were not so prone to negotiate their ideas, but it should be mentioned that, in that case, one member of the group was elaborating the map, while others were giving comments and suggestions.

Other studies investigated computer-based interactions or web-based interactions (at a distance) during CCM. Some authors found that interactions, in those contexts, are on-task most of the time (Chiu, Huang, & Chang, 2000; Chung, O'Neil, & Herl, 1999; Komis, Avouris, & Fidas, 2002), although that was not the case in the van Boxtel & Veerman study (2001). Other researchers pinpointed some difficulties during CCM at a distance. Chiu, Huang, & Chang (2000) noted that slow typing seemed to have disturbed participants who used chat as a communication tool during CCM. They also observed a great amount of repetitive messages, which lead them to conclude that the communication tool should integrate predefined messages. Many other authors also proposed to introduce some kind of structure in the collaborative activity or tool to facilitate content-related interactions and to enhance the depth of processing in a distance mode of communication during CCM. This is the case for Fischer & Mandl (2001) who observed an inadequate division of labour in the distance groups. Van Boxtel & Veerman (2001) observed that student groups need a high amount of effort to coordinate their communication via a CCM tool integrating a chat. Reinhard & al. (1997) found the same, when comparing interactions in a group of students that had to communicate

via a chat to correct computer graphics, either in the condition "manipulable graphics" or in the condition "static graphics". Students in the former condition tended to have a greater need for coordination effort. Suthers, Girardeau, & Hundhausen (2002, 2003) noted a lack of deictic power of CCM tools used at a distance. This could explain why distal participants rarely referenced items that had been previously represented, except for those that had just been added. These authors suggest that tools should support "fluid crosstalk between all representations by making the relationships between different representations and between acts on those representation clear" (p. 13). Chiu, Wu, & Huang (2000) identified four patterns of computer-mediated CCM processes: (1) Concept introduction; (2) Limited concept introduction; (3) Less link establishment; and (4) Proposition construction orientation. Depover, Quintin, & De Lièvre (2004) found that metacognitive interactions and planning interactions were more frequent in contrasted pairings (based on pre-test individual CMap) than in spontaneous ones. However, the last were more collaborative.

Correlations between interactions during CCM and task performance are investigated in four studies (Chiu, Huang, & Chang, 2000; Chung, O'Neil, & Herl, 1999; Depover, Quintin, & De Lièvre, 2004; Sizmur & Osborne, 1997). In general, results show that more interactions and more elaborated, high-level, and complex interactions lead to better performance. There was, however, an exception of one computer-based CCM study (Chung *et al*., 1999) in which the number of chat messages was correlated negatively to performance. Authors explain that split attention effect (Sweller, 1994) could have induced too heavy a cognitive load on participants and that "the use of messages may reflect more the procedural aspects of constructing a knowledge map instead of any substantive discussion about the content" (p. 490).

Only one study explored ***correlations between interactions during CCM and learning*** *(*van Boxtel, van der Linden & Kanselaar studies, 1997, 2000). Results show that the frequency of "elaborative episodes" during CCM is correlated with learning.

Seven studies explored the ***effect of CCM on attitudes***. The results of the study of Czerniak & Haney (1998), conducted with preservice teachers, indicate that CCM could lower anxiety about learning physical science, lower trait anxiety, and increase science achievement. However, it did not have a significant effect on anxiety toward teaching physical science, self-efficacy, and outcome expectancy. Ledger (2003) arrived at the same conclusion for self-efficacy with eighth grade students. However, this author found that female students in the CCM group had a more positive attitude toward science than those that did not construct CMaps. This result was not observed for male students. Attitude toward CM was not significantly altered in groups that experienced CCM with different roles' distribution (assign, rotate, give, or open) according to Chiu (2004). Other authors report opinions from students who experienced CCM. Chang, Sung, & Lee (2003) found that 53% of them were not satisfied with the CCMaps they produced. However, other studies indicate that students appreciate the CCM activity (Liu, 2004; Silander, Sutinen, & Tarhio, 2004). Interpersonal awareness was investigated in the Khamesan & Hammond studies (2004, 2005) comparing online CCM with F2F CCM. In their first study, they found that participants using audio/chat communication showed lower levels of interpersonal awareness and lower performance in a reaction measure compared to F2F and to the chat only group. However, in their subsequent study, there was no significant difference in interpersonal awareness between web-based and non web-based (but distributed) interactions groups, although awareness was higher for web-based groups (specially shared interaction).

Finally, we identified a few ***other issues*** (cognitive preference, gender, etc.), that are explored in some CCM studies. For example, Okebukola & Jegede (1988) found that subjects that have a cognitive preference for *Principles* (i.e. an interest in identifying a relationship between variables or a rule that can be applied to a class of objects, phenomena, or an interest in explaining phenomena), for *Questioning* and for *Application* scored significantly higher in the CCM condition than those who worked individually. No significant difference was found in the CM performance of students with *Recall* cognitive preference in the two learning modes. In a subsequent study, Okebukola (1992) found that students that had six months of CCM experience and that were judged as "good concept mappers" had the highest mean score at a problem solving test than good concept mappers that experienced individual CM and subjects that had no CM experience. The girls outperformed the boys in one problem but the boys displayed better problem-solving abilities in the two others. Girls in the CCM group did better than those in the CM group on two problems. The author concluded that "this may be a hint that cooperative-learning experience is more advantageous than individual work for girls for enhancing problem-solving skills through concept-mapping." (p. 168).

4 Conclusion

This paper (too) concisely described the research that has been done so far in the field of CCM. It is obvious that this is a domain that is becoming increasingly active as we reaffirm the benefits of collaborative learning. Further analysis is needed to better understand how CM fits into this type of learning. We also encourage more sound research in this domain, especially investigating correlations between types of interactions and learning during the CCM activity.

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References

Basque, J., & Pudelko, B. (2004). The effect of collaborative knowledge modeling at a distance on performance and on learning. In A. J. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), *Proceedings of the First International Conference on Concept Mapping (CMC 2004), Pamplona, September 14-17, vol. 1* (pp. 67-74). Pamplona: Universidad Publica de Navarra.

Chang, K.-E., Sung, Y.-T., & Lee, C.-L. (2003). Web-based collaborative inquiry learning. *J. of Computer Assisted Learning, 19*, 56-59.

Chiu, C.-H. (2004). Evaluating system-based strategies for managing conflict in collaborative concept mapping. *J. of Computer Assisted Learning, 20*, 124-132.

Chiu, C.-H., Huang, C.-C., & Chang, W.-T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computers and Education, 34*, 17-25.

Chiu, C.-H., Wu, W.-S., & Huang, C.-C. (2000). *Collaborative concept mapping processes mediated by computer.* Paper presented at the WebNet 2000 World Conference on the WWW and Internet, San Antonio, TX.

Chung, G. K., O'Neil, H. F. J., & Herl, H. E. (1999). The use of computer-based collaborative knowledge mapping to measure team processes and team outcomes. *Computers in Human Behavior, 15*(3-4), 463-494.

Coleman, E. B. (1998). Using Explanatory Knowledge During Collaborative Problem Solving in Science. *The J. of the Learning Sciences, 7*(3&4), 387-427.

Czerniak, C. M., & Haney, J. J. (1998). The Effect of Collaborative Concept Mapping on Elementary Preservice Teachers' Anxiety, Efficacy, and Achievement in Physical Science. *J. of Science Teacher Education, 9*(4), 303-320.

De Simone, C., Schmid, R. F., & McEven, L. A. (2001). Supporting the learning process with collaborative concept mapping using computer-based communication tools and processes. *Educational Research and Evaluation, 7*(2-3), 263-283.

Depover, C., Quintin, J.-J., & De Lièvre, B. (2004). Analyse des effets de deux modalités de constitution des groupes dansun dispositif hybride de formation à distance. *Revue internationale des technologies en pédagogie universitaire, 1*(1), 38-44.

Deutsch, M. A. (1949). A theory of cooperation and competition. *Human Relation, 2*, 129-152.

Esiobu, G. O., & Soyibo, K. (1995). Effects of Concept and Vee Mappings under Three Learning Modes on Students' Cognitive Achievement in Ecology and Genetics. *J. of Research in Science Teaching, 32*(9), 971-995.

Fischer, F., Bruhn, J., Gräsel, C., & Mandl, H. (2002). Fostering Collaborative Knowledge Construction with Visualization Tools. *Learning and Instruction, 12*, 213-232.

Fischer, F., & Mandl, H. (2000). *Construction of shared knowledge in face-to-face and computer-mediated cooperation.* Paper presented at the AERA Annual Meeting, New Orleans, LA.

Fischer, F., & Mandl, H. (2001). *Facilitating the construction of shared knowledge with graphical representation tools in face-to-face and computer-mediated scenarios.* Paper presented at the Euro CSCL, Maastricht.

Fischer, F., & Mandl, H. (2002). *Facilitating knowledge covergence in videoconferencing environments: The role of external representation tools.* Paper presented at the CSCL, Boulder, Colorado.

Gilbert, N. J., & Greene, B. A. (2001-2002). College Students' Collaborative Use of Inspiration to Generate Concept Maps in an Educational Technology Class. *J. of Educational Technology Systems, 30*(4), 389-402.

Herl, H. E., O'Neil, H. F. J., Chung, G. K., & Schachter, J. (1999). Reliability and validity of a computer-based knowledge mapping system to measure content understanding. *Computers in Human Behavior, 15*, 315-333.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education, 77*(1), 95-111.

Karasavvidis, I. (2004). Concept Mapping: Appropriation and Resistance. In P. Kommers (Ed.), *Cognitive Support for Learning: Imagining the Unknown* (pp. 241-251). Amsterdam: IOS Press.

Kealy, W. A. (2001). Knowledge maps and their use in computer-based collaborative learning environments. *J. of Educational Computing Research, 25*(4), 325-349.

Khamesan, A., & Hammond, N. (2004). Synchronous collaborative concept mapping via ICT: Learning effectiveness and personal and interpersonal awareness. In A. J. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), *Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain, 2004*. Pamplona, Spain: Universidad Publica de Navarra.

Khamesan, A., & Hammond, N. (2005). Learning Effectiveness in On-Line Collaborative Concept Mapping via CMC: Comparing Different Mode of Interaction. In P. Kommers & G. Richards (Eds.), *Proceedings of ED-MEDIA 2005, Montreal, June 27 to July 2, 2005* (pp. 3179-3186). Norfolk, VA: Advancement of Computing in Education (AACE).

Kinchin, I. M., De-Leij, F. A. A. M., & Hay, D. B. (2005). The evolution of a collaborative concept mapping activity for undergraduate microbiology students. *J. of Further and Higher Education, 29*(1), 1-14.

Komis, V., Avouris, N., & Fidas, C. (2002). Computer-Supported Collaborative Concept Mapping: Study of Synchronous Peer Interaction. *Education and Information Technologies, 7*(2), 169-188.

Ledger, A. F. (2003). *The Effects of Collaborative Concept Mapping on the Achievement, Science Self-efficacy and Attitude Toward Science of Female Eighth Grade Students.* University of Massachussetts Lowell.

Lee, Y., & Nelson, D. W. (2005). Viewing or visualising - which concept map strategy works best on problem-solving performance? *British J. of Educational Psychology, 36*(2), 193-203.

Liu, X. (2004). Using Concept Mapping for Assessing and Promoting Relational Conceptual Change in Science. *Science Education, 88*, 373-396.

Mead, G. H. (1934/1974). *Mind, self, and society from the standpoint of a social behaviorist*. Chicago: Chicago University Press.

Mugny, G., Perret-Clermont, A., & Doise, W. (1981). Interpersonal coordinations and sociological differences in the construction of the intellect. In G. M. Stephenson & J. H. Davis (Eds.), *Progress in Applied Social Psychology, Vol I* (pp. 315-343,). New York: Wiley.

Nesbit, J. C., & Adesope, O. O. (submitted). Learning with Concept and Knowledge Maps: A Meta-Analysis. *Review of Educational Research*.

Okebukola, P. A. (1992). Can Good Concept Mappers be Good Problem Solvers in Science? *Research in Science and Technological Education, 10*(2), 153-170.

Okebukola, P. A., & Jegede, O. J. (1988). Cognitive preference and learning mode as determinants of meaningful learning through concept mapping. *Science Education, 72*(4), 489-500.

Osmundson, E., Chung, G. K., Herl, H. E., & Klein, D. C. (1999). *Knowledge mapping in the classroom : A tool for examining the development of students' conceptual understandings* (Technical report No. 507). Los Angeles: CRESST/ University of California.

Reinhard, P., Hesse, F. W., Hron, A., & Picard, E. (1997). Manipulable graphics for computer-supported problem solving. *J. of Computer Assisted Learning, 13*, 148-162.

Rogoff, B., & Lave, J. (1984). *Everyday cognition : its development in social context.* Cambridge, MA: Harvard University Press.

Roth, W.-M., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. *Science Education, 76*(5), 531-557.

Roth, W., & Roychoudhury, A. (1993). The concept map as a tool for the collaborative construction of knowledge: A microanalysis of high school physics students. *J. of Research in Science Teaching, 305*, 503-554.

Salomon, G. (Ed.). (1993).«*Distributed cognitions: psychological and educational considerations*. Cambridge, Angleterre: Cambridge University Press.

Silander, P., Sutinen, E., & Tarhio, J. (2004). Mobile Collaborative Concept Mapping: Combining Classroom Activity with Simultaneous Field Exploration. *Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education*.

Sizmur, S., & Osborne, J. (1997). Learning processes and collaborative concept mapping. *International J. of Science Education, 19*(10), 1117-1135.

Slavin, R. E. (1990). *Cooperative learning: Theory, research, and practice.* Boston: Allyn and Bacon.

Stoyanova, N., & Kommers, P. (2002). Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving. *J. of Interactive Learning Research, 13*(1/2), 111-133.

Suthers, D. D., Girardeau, L. E., & Hundhausen, C. D. (2002). *The roles of representation in online collaborations.* Paper presented at the AERA 2002, New Orleans.

Suthers, D. D., Girardeau, L. E., & Hundhausen, C. D. (2003). Deitic roles of external representations in face-to-face and online collaboration. In B. Wasson, S. Ludvigsen & U. Hoppe (Eds.), *Designing for change in networked learning environnements, proceeding of the international conference on computer-support collaborative learning* (pp. 173-182): Kluwer academic publishers.

Suthers, D. D., & Hundhausen, C. D. (2001). Learning by constructing collaborative representations: An empirical comparaison of three alternatives. In P. Dillenbourg, K. Eurelings & K. Hakkarainen (Eds.), *European perspectives on computer-supported collaborative learning, Proceeding of the first European conference on computer-supported collaborative learning* (pp. 577-584). Maastrict: Universiteit Maastricht.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*, 295-312.

van Boxtel, C., van der Linden, J., & Kanselaar, G. (1997). Collaborative Construction of Conceptual Understanding: Interaction Processes and Learning Outcomes Emerging From a Concept Mapping and a Poster Task. *J. of Interactive Learning Research, 8*(3/4), 341-361.

van Boxtel, C., van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and instruction, 10*, 311-330.

van Boxtel, C., & Veerman, A. (2001). *Diagram-mediated collaborative learning diagrams as tools to provoke and support elaboration and argumentation.* Paper presented at the Euro CSCL, Maastricht.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological process*. Cambridge: Harvard University Press.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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COMPARATIVE STUDY OF MENTAL MODEL RESEARCH METHODS: RELATIONSHIPS AMONG ACSMM, SMD, MITOCAR & DEEP METHODOLOGIES

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Abstract. Measuring and assessing mental models of individuals and teams requires the capturing and analysis of key latent variables. This paper presents and compares four different research methods (ACSMM, SMD, MITOCAR and DEEP) that capture and create a conceptual representation of individual and team mental models. These methods use qualitative and quantitative techniques to investigate a single comparison of different groups or individuals' mental models with another group's mental model or to investigate the comparison of a group or individuals' mental model with themselves at a later time.

1 Introduction

Various fields of human science investigate many factors associated with cognition and mental models. Scientists are continually developing new techniques to capture key latent variables associated with cognition. One specific area of interest is with internal conceptual systems (mental models and schemata). These conceptual systems are theoretical constructs of science that are not observable. Therefore, individuals have to externalize their conceptual systems, and changes in these externalizations are interpreted as changes in the underlying conceptual systems; i.e. researchers can only learn of conceptual systems if individuals communicate their systems (Seel, 1991). A key research interest is to capture and/or create conceptual representations of these internal conceptual systems.

A common analytical requirement is to compare conceptual representations of one group or individual with the representations of another group or individual or even with oneself at a later time. These analytical comparisons are made to represent differences and change of cognitive function. As new techniques and methods are being developed, the question of a valid and reliable measurement of change is one of the central problems of conceptual systems research (Seel, 1999). As such, there are two comparative situations that merit considerations: 1) a single comparison of different groups or individuals with another group and 2) the comparison of a group or individual with themselves over time. Accordingly, the psychological and educational diagnosis of internal conceptual systems presupposes repeated measurements of these systems over the course of a given process (Ifenthaler & Seel, 2005), both for individual and team performance.

Given these research interests, several researchers are conducting a series of studies evaluating four different research methods (ACSMM, SMD, MITOCAR and DEEP) that are specifically aimed at comparing internal conceptual representations of both individuals and teams. The purpose of the study is to determine the strengths for each method, to understand how these tools are unique, and to determine if the specific techniques could be collectively used to ultimately further mental model research and theory development. Each of these research methods employ concept maps as part of the conceptual system elicitation and/or part of the analysis results. Due to the complexity of the studies, this paper will not present the preliminary findings, but will describe each method as well as the series of comparative studies.

2 Methodology Descriptions

While the initial rationale for each method was different, this section seeks to describe each method. The methods employ various techniques (quantitative, qualitative) but each use concept maps as part of their methodological tasks.

2.1 Analysis Constructed Shared Mental Model (ACSMM) Methodology

The ACSMM methodology (O'Connor & Johnson, 2004) was developed as a method to determined sharedness among team members. The basic technique involved eliciting concept maps from individual teammates and then using the ACSMM phases to analyze the individual concept maps thereby creating a single concept map that represents the shared components of the team.

Through concept mapping, similarity of mental models can be measured in terms of the proportion of nodes and links shared between one concept map (individual mental model) and another (Rowe, 1995). Utilizing qualitative techniques with an aggregate method of creating an analysis constructed shared mental model (ACSMM), we can capture a more descriptive understanding than by using quantitative techniques.

The ACSMM technique translates individual mental models into a team sharedness map without losing the original perspective of the individual, thereby representing a more accurate representation of team sharedness. The methodology includes several phases: elicitation design and preparation, elicitation of individual team member mental models, coding of individual data, analysis of data to determine what is shared among team members, and construction of the team conceptual representation.

Phase I: Elicitation Design—In order for individuals to create a fully constrained or semi-constrained concept map, a topic analysis is preformed to generate the list of related terms. The process of analysis focuses on determining the various components of a concept and logical relationships, if any. Many topics are ill-structured and allow for multiple logical arrangements. Once the components of the topic have been generated, these terms are then used to help elicit individual mental models.

Phase 2: Individually Constructed Mental Model (ICMM) Elicitation—Prior to the data collection process, a guided practice is provided to demonstrate how to create a concept map. Participants also create a simple concept map by themselves or with others. Concepts maps are reviewed and feedback is provided. If subsequent elicitations are to take place, no guided practice is required. Individuals are then ready to create their individually constructed mental model (ICMM).

Phase 3: ICMM Coding—In order to compare and measure a degree of sharedness in ICMMs, factors such as concepts, links, and cluster combinations are used in analyzing individually constructed concept maps (Doyle, 1998; Jonassen, 1997; Novak & Gowin, 1984). Coding also considers implicit relationships between concepts and structural factors such as directional links and sequence indicators. If the topic of study focuses on a process task, it would be appropriate to use causal measures (directional links, sequence of concepts, and clusters) rather than hierarchical measures and cross-links for coding as suggested by Novak and Gowin (1984).

The ACSMM method accounts for map relatedness at the concept, link, and cluster levels. Because maps appear so unique, the coding strives to reduce the logical, spatial, and structural information and code them so that comparisons among maps can be made. The coding process involves documenting the explicit information on the maps as well as making assessments regarding implicit information. This assessment allows for explication of implicit relationships by considering the spatial, structural and logical information in the map. The coding process involves studying concepts, links, and clusters within each ICMM. The process of coding is much like the process of interpretation. Each map is analyzed and then the researcher codes their interpretation in a spreadsheet or other appropriate tool.

Phase 4: Shared Analysis—After coding the ICMMs, the next step involves an analysis of the ICMM dataset to determine what items were shared by team members. The data tables resulting from ICMM coding are compared for similarity across team members. We suggest starting with a sharedness criterion of 50%. Then determine the shared items for that sharedness level. Depending on the sharedness level sensitivity, the level can be adjusted up or down to increase or decrease the sensitivity. The percentage or number of team members sharing each item is recorded, and all shared items are carried forward for use in constructing the representation of the team's shared mental model, the ACSMM.

Phase 5: ACSMM Construction—The analysis constructed shared mental model (ACSMM) is constructed from the shared ICMM dataset generated in Phase 4. This construction process includes the following steps: Step 1: List Shared Concepts, Step 2: Configure Shared Clusters, Step 3: Configure Shared Links, and Step 4: Configure Non-linked Concepts. The ACSMM methodology is repeated for each subsequent set of concept maps. Once the sharedness between all ICMMs has been identified, the analysis constructed shared mental models can be compared looking at change over time for a specific team or the ACSMM s can be compared among teams to show variation of shared mental model among teams.

2.2 Surface, Matching, and Deep Structure (SMD) Methodology

The Surface, Matching, and Deep Structure (SMD) methodology was developed as a means of calculating the mental model development of students using three different instructional treatments. The basic technique involved eliciting concept maps from individuals at multiple intervals over time as they use a specific instructional intervention. SMD is then used to determine if the concept maps for the individuals change over time and then combine the concept maps of students in each treatment group and compare the findings among treatment groups to determine the effect.

The question of a precise assessment of mental models led to the development of a new methodology named SMD-Technology (Ifenthaler, 2006; Seel, Ifenthaler, & Pirnay-Dummer, 2006). As a basis for the assessment of models, SMD-Technology uses graphical drawings (concept maps) or natural language statements (that is then converting into a concept map) by the subjects. Both, the graphical drawings or natural language statements are transferred into a dataset for further analysis. The SMD-Technology is composed of three levels - Surface, Matching, and Deep Structure.

Phase 1: Surface Structure Analysis—The first level of SMD-Technology constitutes the Surface Structure, on which a rapid and economical assessment of the number of propositions (2 linked nodes) is made possible. The Surface Structure θ is defined as the sum of all propositions P in an individual model.

$$\theta = \sum_{i=0}^{n} P_i \tag{1}$$

Phase 2: Structural Properties Analysis—The assessment of the structural properties of the externalized models is realized on the Matching Structure. The Matching Structure μ is defined as the quantity of links L of the shortest path between the most distant nodes K.

$$\mu = \max_{i,j}\{d(i,j)\} \tag{2}$$

Phase 3: Deep Structure Analysis—The third SMD-Technology level is defined as the Deep Structure. This is the level on which the models are assessed in terms of their semantic structure. The Deep Structure δ is calculated as the similarity (Tversky, 1977) between a shared group model M_{gr} or a domain-specific expert model M_{ex} and the individually assessed model M_i.

$$\delta = \frac{f(A \cap B)}{f(A \cap B) + \alpha \cdot f(A - B) + \beta \cdot f(B - A)} \tag{3}$$

2.3 Model Inspection Trace of Concepts and Relations (MITOCAR) Methodology

Model Inspection Trace of Concepts and Relations (MITOCAR) is a software tool that is based on mental model theory (Seel, 1991) and uses natural language expressions as input data for model re-representation instead of using graphical drawings by the subjects. This is made possible by parsing and corpus linguistics technologies that are similar to those used to implement automated learning of concept hierarchies from text corpora to construct ontology (Maedche et.al. 2002).

One of the goals of MITOCAR is to dig deeper into the semantics of models, especially shared models within groups of experts. This is done during a phase of assessment and an inferential phase. During the assessment phase of MITOCAR, subjects usually go through two different rounds. In the first round they only provide a number of natural phrases (usually sentences) about their specific subject matter. Before the second round, the parser extracts the most frequent concepts from the text corpus of the group and connects them to pairs of concepts.

In the second round the subjects rate how close the concepts are and how sure they are about their assessment. The participants also cluster their concepts from a random list into a list of groups – a method that is sometimes used in knowledge tracking (Janetzko, 1996). Additionally, subjects rate the plausibility of their fellow group members' source phrases.

From this data MITOCAR calculates a proximity vector that represents the whole model that is used to build the model representation (concept map). These data allow one to derive models and even graphical models (Fruchterman & Reingold, 1991; Ganser & North, 1999) that can then be compared in several new ways. This is done with the inferential modules of MITOCAR.

While the semantic comparison of MITOCAR uses traditional measures of similarity (Tversky, 1977) the technology of structural comparison is unique to MITOCAR and can compare models from different subject domains (Pirnay-Dummer, 2006). Up to now we have succeeded in re-representing the models graphically (concepts and structures) on non-directed graphs and comparing them by using conceptual, structural and combined similarity measures. Those measures are controlled using different statistical tests and controls for homogeneity and reliability of the group-consensus models, multidimensional scaling (MDS) of the proximity vectors to test for the representation in 2D and for the comparison and tracking of model complexity.

The final outputs of MITOCAR are the graphical representations to assess a group consensus model from any subject domain and the comparison between different groups of experts. For both outputs there are automated reports which are computing, presenting and interpreting all the above mentioned measures. It has also been investigated how the results of MITOCAR can be used in needs assessment (Pirnay-Dummer, 2006). In addition, the methods of MITOCAR have been applied successfully to tracking user behavior in e-learning environments (Dummer & Ifenthaler, 2005).

Due to the modular design of MITOCAR the assessment tools (re-representation of models by means of natural language, parsing and graph theory) can be separated from the inferential tools (comparing structures and semantics and both). This opens the MITOCAR technology to use on all kinds of model-related data.

2.4 Dynamic Evaluation of Enhanced Problem-solving (DEEP) Methodology

The Dynamic Evaluation of Enhanced Problem-solving (DEEP) methodology is based on a view of learning as becoming more expert-like (Ericsson & Smith, 1991) and more skilled in higher-order causal reasoning and problem solving (Grotzer & Perkins, 2000). The learning-as-becoming-like-an-expert perspective treats learning as a continuing process of growth rather than a single end-point measurable by a simple test. A fundamental assumption is that with regard to complex task performance it is possible to predict performance and assess relative level of expertise by examining a person's conceptualization of the problem space (a problem conceptualization that suggests likely solution alternatives) for specific complex problems.

Learning assessment in DEEP involves: 1) identifying characteristic problems in a particular complex task domain; 2) eliciting both expert and novice patterns of responding to these problems; 3) representing these responses (problem-solution conceptualizations) in a standard form; 4) measuring similarities and differences among experts and novices; and, 5) assessing changes in problem-space conceptualizations over time and with experience.

Learners, either individually or in small groups, are presented with a short problem scenario. They are asked to identify the most relevant factors and issues to consider in developing a solution and then to illustrate the specific nature of relationships among these factors. These annotated causal representations are compared to prior representations and to those of experts to determine progress of learning. Three levels of analysis were applied to these representations. Simple counts of nodes, links, and words per node or link constituted a surface level analysis. Determining the extent of similar nodes and links and how they were connected constituted the structural analysis. Understanding what is said about a particular node or link constituted the semantic analysis. Because the tool allowed nodes and links to be named according to respondent preferences, it was not possible to easily separate the structural and semantic analysis. One purpose of the study was to determine the extent to which a semantic analysis would be required to determine relative level of expertise.

A unique aspect of the DEEP methodology is that it is intended for complex problems involving causal relationships that are interrelated and that may change over time. Moreover, a variety of graphical representations (e.g., semantic networks, flowcharts, causal diagrams, etc.) can be accommodated in this methodology. The graphical representations are converted into standard causal representations (i.e., annotated causal influence diagrams). The reason for using causal representations as the basis for analysis is that such representations reflect internal relationships among factors and components (i.e., problem dynamics) and causal representations can be derived from many other graphical representations when the appropriate documentation is provided (e.g., the descriptions of individual factors). The DEEP methodology supports assessments of individual learning in problem-centered instructional modules, which can be used in evaluating problem-centered instructional programs (Baker, 1999; Herl et al., 1999). The data provides information about how well individual learners are doing in specific problem-centered modules. This enables teachers to adjust instructional supports appropriately and it enables learners to adjust their learning strategies. Additionally, instructional designers are provided with information on which to base specific modifications to the structure and sequence of various learning activities.

Variations of this methodology have been effectively demonstrated in simpler domains (Herl et al., 1999; Novak, 1998; Schvaneveldt, 1990). Those who have employed an analogous method for simpler learning tasks have relied on: simple quantitative measures for measures of similarity to expert responses (e.g., presence/absence of salient features and their location in a concept map); and, qualitative analysis of responses, which are notoriously time-intensive and costly and, consequently, hardly ever used when a laboratory or demonstration effort of a learning environment or instructional system scales up to full-scale implementation and deployment.

2.5 Methodology Comparison

The general characteristics of each of these methods have similarities and differences (Table 1). In each case, the methodology collects data that then is transformed before specific analysis can take place. Analytical methods for each method convert the data to emphasize a decomposition or composition of the initial data set. Comparisons describe the functionality of the methods to simultaneously compare/analyze unlimited or paired groups/individual data.

3 Studies: Method Comparisons

In order to meet the goals of our research (determine the method strengths, unique characteristics, and collective viability), we have setup a series of comparative studies to answer these questions. A series of pair-wise comparative studies are followed in order to detect analytical differences among the mythologies. There are two points of method comparisons: data conversion techniques and data analysis techniques.

Each of these methodologies have been used in specific settings, however the work represented in these comparisons is the first project utilizing a single set of data to compare the results of these four methodologies. There are six studies involving two parts each. The studies compare the following pairs of methods: 1) ACSMM & MITOCAR, 2) SMD & MITOCAR, 3) ACSMM & SMD, 4) DEEP & SMD, 5) DEEP & MITOCAR, and 6) DEEP & ACSMM.

Method	Data Collection	Analysis	Data Conversion	Comparison Fxn
ACSMM	Concept Map	Qualitative with Descriptive Statistics—analysis is done mostly by hand	Structural Decomposition into 3 Key Categories (manual), Structural Re-composition into 1 Representation	Unlimited comparisons, show details relating to concepts
SMD	Concept Map or Natural Language	Quantitative—analysis is calculated using tools	Structural Decomposition into 3 Key Categories (manual)	Unlimited comparisons
MITOCAR	Natural Language	Quantitative—analysis included multiple calculations using tools	Structural Composition into 1 Category (automatic)	Paired comparisons for semantic and structural model distance measures
DEEP	Annotated Influence Diagrams	Quantitative/Qualitative —analysis is done mostly by hand	Structural Decomposition into 3 Key Categories (automatic)	Unlimited comparisons, show details relating to concepts

Table 1: Methodologies' features and techniques comparisons.

We first look at the data analysis techniques. Since each method has different techniques for data conversion prior to data analysis, the initial comparison among the methods will focus on the specific analytic techniques employed. As such, the comparisons begin with the same dataset in order to control for the analysis phase of each method. This involves taking a set of decomposed data from concept maps or natural language and the analysis techniques used in each method will be employed and the output will be compared.

The second part compares the data conversion techniques. This involves collecting data according to the method specifications and then going through the process of data conversion. The converted data are compared for similarities and differences.

For example, the application of the SMD-Technology in different subject domains and the comparison with other quantitative methodologies, e.g. MITOCAR (Pirnay-Dummer, 2006), or qualitative methodologies, e.g. ACSMM (O'Connor & Johnson, 2004) and DEEP (Spector & Koszalka, 2004), could cross-validate the SMD-Technology (and vice versa) and give a more detailed understanding of the changes of mental models within individuals and teams.

4 Summary

From the study of these methodologies, we hope to better qualitatively and quantitatively represent individual and team mental models thereby facilitating greater understanding of the notion of individual and team processes and the development of mental models. We hope to better understand mental model development by the comparison of individuals to experts.

Further, by comparing the teams at various points during team processes, we should be able to determine how team metal models change over time. With each methodology we test the progression/development of conceptual representations with each other from the initial state to the post state and the similarity between the individually constructed conceptual representations. Not only will this information benefit further study in individual and team dynamics, but also if we can identify how team mental models change over time and find indicators of why they change, we should be able to develop methods for improving overall individual and team performance.

Conducting experiments for cross validation gives us a chance to add quantitative control for qualitative assessment methods looking at individuals and aggregation to be used for teams. Likewise this type of experimentation gives us added qualitative control for quantitative assessment methods.

References

Baker, E. (1999, July). Technology: How do we know it works? Paper presented at the Secretary's Conference on Educational Technology, July 12-13, 1999, Spector – Page 18 of 23 Washington, D.C. (Available at http://www.ed.gov/Technology/TechConf/1999/whitepapers/paper5.html).

Doyle, J. K., Radzicki, M. J., & Trees, W. S. (1998). Measuring Change in Mental Models of Dynamic Systems: An Exploratory Study.Unpublished manuscript.

Dummer, P., Ifenthaler, D. (2005). Planning and assessing navigation in model-centered learning environments. Why learners often do not follow the path laid out for them. In G. Chiazzese , M. Allegra, A. Chifari & S. Ottaviano (Eds.), Methods and technologies for learning, pp. 327-334. Southampton, Boston: WIT Press.

Ericsson, K. A., & Smith, J. (Eds.) (1991). Toward a general theory of expertise: Prospects and limits. New York: Cambridge University Press.

Fruchterman, T.M.J., & Reingold, E.M. (1991). Graph drawing by force-directed placement. Software - Practice and Experience, 21 (11), 1129-1164.

Ganser, E.R, & North, S.C. (1999). An open graph visualization system and its applications to software engineering. Software - Practice and Experience, 00 (S1), pp. 1-5.

Grotzer. T. A., & Perkins, D. N. (2000, April). A taxonomy of causal models: The conceptual leaps between models and students' reflections on them. Paper presented at the National Association of Research in Science Teaching (NARST), New Orleans, LA, 28 April - 1 May 2000.

Herl, H. E., O'Neil, H. F., Jr., Chung, G. L. W. K., Bianchi, C., Wang, S., Mayer, R., Lee, C. Y., Choi, A., Suen, T., & Tu, A.(1999). Final report for validation of problem solving measures. CSE Technical Report 501. Los Angeles: CRESST.

Ifenthaler, D. (2006, in press). Diagnose lernabhängiger Veränderung mentaler Modelle. Entwicklung der SMD-Technologie als methodologisches Verfahren zur relationalen, strukturellen und semantischen Analyse individueller Modellkonstruktionen. Freiburg: Universitäts-Dissertation.

Ifenthaler, D., Seel, N.M. (2005). The measurement of change: learning-dependent progression of mental models. Technology, Instruction, Cognition and Learning, 2 (4), 317-336.

Janetzko, D. (1996) Knowledge Tracking. A Method to Analyze Cognitive Structures. Freiburg: IIG-Berichte 2.

Jonassen, D. H., Reeves, T. C., Hong, N., Harvey, D., & Peters, K. (1997). Concept Mapping as Cognitive Learning and Assessment Tools. Journal of Interactive Learning Research, 8(3/4), 289-308.

Maedche, A., Pekar, V., Staab, S. (2002) Ontology learning part one - on discovering taxonomic relations from the web. In Proceedings of the Web Intelligence Conference, pp. 301-322. Springer

Novak, J. D. (1998). Learning, creating and using knowledge: Concept maps as facilitative tools in schools and corporations. Mahwah, NJ: Erlbaum.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. Cambridge Cambridgeshire; New York: Cambridge University Press.

O'Connor, D.L., Johnson, T.E. (2004). Measuring team cognition: Concept mapping elicitation as a means of constructing team shared mental models in an applied setting. First International Conference on Concept Mapping, September 14-17, 2004, Pamplona, Spain.

Pirnay-Dummer, P. (2006, in press). Expertise und Modellbildung: MITOCAR. Freiburg: Universitäts-Dissertation.

Rowe, A. L., & Cooke, N. J. (1995). Measuring Mental Models: Choosing the Right Tools for the Job. Human Resource Development Quarterly, 6(3), 243-255.

Schvaneveldt, R. W. (Ed.) (1990). Pathfinder associative networks: Studies in knowledge organization. Norwood, NJ: Ablex.

Seel N.M., Ifenthaler, D., Pirnay-Dummer, P. (2006, in press): Mental Models and Problem Solving: Technological Solutions for Measurement and Assessment. In: Strobel, J. Jonassen, D. Learning by Modelling Systems, Mawah, NJ: Erlbaum

Seel, N.M. (1991). Weltwissen und mentale Modelle. Göttingen: Hogrefe.

Seel, N.M. (1999). Educational diagnosis of mental models: Assessment problems and technology-based solutions. Journal of Structural Learning and Intelligent Systems, 14 (2), 153-185.

Spector, J. M., & Koszalka, T. A. (2004). The DEEP methodology for assessing learning in complex domains (Final report to the National Science Foundation Evaluative Research and Evaluation Capacity Building). Syracuse, NY: Syracuse University.

Spector, J. M., Dennen, V. P., & Koszalka, T. A. (2005). Causal maps, mental models and assessing acquisition of expertise. Technology, Instruction, Cognition and Learning, 3.

Tversky, A. (1977). Features of similarity, Psychological Review, 84, 327-352. From: Spector, J. M., Dennen, V. P., & Koszalka, T. A. (2005). Causal maps, mental models and assessing acquisition of expertise. Technology, Instruction, Cognition and Learning, 3.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

COMPLEX THOUGHT, CONCEPTUAL MAPS AND CMAPTOOLS

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Abstract. The increasing percentage of dyslexia together with low cultural levels which have been noticed in the most industrialized western countries denounce a diffuse and alarming incapacity in cognitive reading of reality interrelated to the own culture.
So, where's the problem? It 's in the lack of synchronization between the world's shape (things around us) and the model of access to the world as it is practiced and taught.
The *organ of language* of new generations develops in a context where its contents are given in a sketchy, chaotic way, in constant evolution with demands for competence to handle this new modality.
If for thousands of years a specific cultural model that had used the linearity as a representative form of the linguistic meaning (e.g. the alphabets) is prevailing, the learning brains has adapted to that method. On the other hand, when the reticular complexity of representative forms is prevailing like nowadays, it'll be necessary to use teaching models based on this new competence
For some years, we are experimenting competent models for the development of The *language organ* that show how the attribution of meaning and language competence (which are basic strategies and cognitive categories already present at the natural language-thought level) become decisive for the development of the scientific and organized thought, because for a child "*the voice of reality as for a mathematician is in the symbol's meaning".* (R.Thom1988*).*
This paper describes the experiences and the practices (*teaching based on narration, teaching with concrete aims using conceptual maps and hyper-textual writing as for communication and representation*) that help the natural development of language faculties in normal daily teaching and, in this specific case, they combine competence and meta-cognition in order to teach the mind to learn and to use computer technology and Internet (real cognitive branches for the own use) in the most profitable way, thanks to CmapTools.

1 Introduction

We have worked for six years on the plan and realization of an ongoing educational method that involves pre-school and school children (2/3-13 years old), teachers and university students (pre-service teachers). In some classrooms of "Volponi" School all regular educational activities are based on the linguistic learning, concept maps and hyper-textual writing that are used to organize and retell one's knowledge. Emphasis was initially given to develop superior forms of children mental processes, i.e. *from concept formulation to organized scientific thought, from linear writing to hyper-textual writing*. Subsequently, this educational experience gave not only excellent results as to the premises, but also astonishing opportunities to reflect on the capacity to prevent or "rehabilitate" particular cognitive pathologies /problems of knowledge such as dyslexia.

Instruction based on story-telling, instruction pursuing concrete objectives, retelling knowledge through concept maps and CmapTools (Cañas et al. 2004), as a system of hyper-textual writing (Giombini, 2004) "create" a framework that teaches children to reflect, from the very early childhood, on the value of scientific thought, on the cognitive role of science, on the centrality of language analysis and on the importance of the logic and standard languages.

In the special form of social interaction occurring in classrooms -- meaning attribution together with linguistic competence, concept maps (Novak, 1984) and writing adaptation to the new interface, i.e. the computer, (hyper-textual writing)-- are "routine" instruments of a Language Acquisition Support System (Bruner, 1983) that make a Language Acquisition Device (Chomsky, 1965) possible.

2 Cognitive problems in societies of communication

Time dedicated to communication in advanced societies is so remarkable to make communication be the main human activity. A widespread and obstinate belief says that skills and culture correspond to mass media exposure in a directly proportional manner.

Against, the increasing percentage of dyslexia together with low cultural levels that have been brought to attention in the past few years (*Programme for International Student Assessment* OCSE) denounce a diffuse and alarming incapacity in cognitive reading of reality interrelated to one's culture.

In 1934, at the beginning of our educated society, Vygotsky (1962) already identified instruction not only "as one of the main concept sources for children", but " also as a powerful tool that directs children's growth; instruction establishes the fortunes of their overall mental development".
So, where's the problem? It's in the lack of synchronization between the world's shape (things around us) and the model of access to the world as it is practiced and taught.

Chomsky (1971) claimed: "the main problem to interpret the world is to determine the way, through which human beings proceed in their interpretation. It is about studying the interaction between the human mind, a particular and complex system given to the human being biologically and the physical and social world".

The genetic program of the faculty of language represents only a part of the whole story, the other part is to searched in a support system.

Meaning attribution and *linguistic competence* are essential cognitive strategies and categories. They are indispensable for "*the cognitive reading of the world*"; they are evidences of the specific-species faculty of language, an expression of linear and sequential thoughts and also of reticular and process thoughts. When a cultural form using linearity as a representative module (e.g. alphabetical sequences) of meanings, in particular language meanings, has prevailed for millennia, learners' brains are stirred by methods tuned to that modality and fit in it. On the other hand, when the reticular complexity of representative forms prevails today, it will be necessary to use teaching models based on this new competence.

3 Human language: an output and instrument of intelligence

Given the fact that language faculty has been determined by evolution (with Darwin or Chomsky as for times and methods) or the fact that language in the form of human language has become the most powerful cultural meme (R.Dawkins, 1976), language is what has determined the "form" of human intelligence, i.e. the ability to understand, produce and transform "culture".

Culture is such a powerful instrument in elaborating plans, i.e. new abilities of acting in the world (Popper, 1989), that its effects can overcome, to a certain extent, the ancient genetic processes from which it was born. Human language is an open and complex system, tool and product of human mind.

Language acquisition or indeed the innate faculty proper of the human species is compared by Chomsky (1988) to the development of an organ subject to natural physiological laws: like any other organ, it can fully develop only if all necessary parameters have been followed.

In theory, three factors need to be considered:
1. the genetically determined principles of language faculty (competence) and of the systems that form the architecture (structure) mind/brain;
2. the culturally-determined principles of the form of knowledge contents and of the means, through which principles are acknowledged;
3. the 'habitat' – also culturally-determined, even though it may not be necessarily along with the previous point– in which the child's knowledge as an individual is formed.

Of the three factors under consideration, only points 2 and 3 have changed significantly in recent years; but, if it's true that the cultural project never erases the genetic project it however models the skills.

Vygotsky (1962) developed the idea that the development of thought is based on the centrality of social interaction and sign systems and that the individual uses the signs of mediation to master and direct his/her own thoughts. Verbal language is the main occasion for communicative interaction. Words are *"the tool"* of thoughts. Even in Popper's "open world" the three dimensions of reality -- nature, self conscience (psyche) and the world of objects (respectively world 1, 2 and 3)-- interact reciprocally thanks to reasoning, i.e. the essence of human language. Consequently, the physical world is not causally closed but it can be modified by the human mind that, in its turn, can be altered by its ideas.

"The organ of language" of new generations develops in a context, in which knowledge contents are given and offered in a fragmentary, chaotic and evolving manner.

Totally immersed in a computerized civilization, the child's mind can only absorb (Salomon, 1979) a "random" model of a culture that values more fragments and single parts instead of the whole. However, "Nothing has already been, anything is possible" (Popper, 1989).

4 Children, stories and the world

Knowing how "to read the world" for a child (but also for adults) means being aware of his/her own mental constructions, of the interaction between them and the perspective competence of reality observation by selecting all the facts observed. It's the human capacity to make inferences on reality: continuously, we relate events one to the other, we make categories, we classify, we deduct, we select information in order to solve our problems…; we always proceed through trial and error, in a continuous adaptation of what we have learned to create new concept matrices that can maintain the experience from which they were born, and, at the same time, can be "significantly useful" for new experiences.

According to Vygotsky (1962), the development of superior forms of mental processes occurs in children in one direction that proceeds through education from the external reality to the child's internal one, from the social world to the child's intra-personal skills. Learning directs the development of the child through a gradual internalization of his/her intellective processes that are activated by his/her social interaction. In particular, words "*first act as the means of concept formation, then they become their symbol*". Vygostky (1962) used to examine all aspects pertaining the particular structure of children's knowledge proposed by instruction: language, scientific thought and mainly written language acquisition as a symbol system of superior mental level that is the essential mediation and that affects the way to make categories, reasoning and thinking in a way we still do not know well.

A *cognitive management of systems and their interactions,* careful to relations between variables and parameters that characterize states and transformations, *help to see and represent* situations in terms of "equalities" (balance, conservation, symmetry, equivalence, invariable, isomorphism etc.) and "inequalities" (up to the inevitable casualty and irreversibility), and construct a net of thinking strategies (looking, doing, telling, etc.), which gradually elaborate new cognitive sceneries more and more defined in shape, stability , and efficiency, in learning proceeding .

Usually, the student (teacher?) is left alone with these needs and often he/she is not able to understand reality in articulate/coherent modes. On the contrary, there is a need for a planned and structured mediation so that knowledge and skills (at all levels) can improve in a successful way: if we do not build knowledge and mental tools necessary to understand, we will not be able to understand and we will refuse to understand.
So, what is the task of adults considered as " *translators of meaning*?"

We can not forget as Vygotsky (1962) would say, that learning within every human being occurs through the mediation of verbal language and always occurs "*with the collaboration of an adult, who gave explanations, asked questions and made corrections*".

Let's remember that teaching means "*show through finger"* that is we have to add the nominal meaning to the demonstrative one to give children the most possible information because *"In any moment there is more than the eye can see, more than the ear can hear, some areas or sights remain unexplored. Nothing is separately experimented but always relating to adjacencies to the sequential events and memories of preceding experiences…"* (Lynch 1964)

I agree with Umberto Eco who (2005) says "*I am among them, who think that also scientific knowledge should take the form a story-telling "* to help the child reflect on the "magic" of experience through activities that teach how to see, listen, and remember in order to be able to do things and tell stories and activities. "Story-telling" that make the "*universe of fantasy—where we imagine worlds to create stories*—distinct but close to *universe of reality – where we crate stories to understand the world".*

5 Stories, maps, texts and hyper-texts to "read/write" the "world" "Volponi" School's experience

In our project we try to foster the development of language faculty through readings oriented to make the child deal first with the words and story, then with the *signs* considered as means that allow to remember, understand, rebuild and translate. All instruction activities begin and end with a reading: the first reading is the teacher's reading and it creates the context for learning, the second reading is the student's reading. The student "retells" his/her writing to show how much he/she has understood, remembered, related … In this way, the child exercises his/her critical thinking; through the reading of his/her signs, the child develops his/her process of abstract synthesis.

Examples of activities related to the child's crucial learning phases follow: (1) "Scribbles" by 3-5 year-old children, with no writing. (2) The phase when the child learns how to write and contextually learns how to use writing software and CmapTools (5/6 years). (3) The cultural acquisition of language principles and rules (7 years)—(4) The competent use of hypertext writing (8/12 years)

5.1 Drawings and concept maps by 3-5 year-old children with no writing

The *language faculty* shows all its complexity in children: expression of sequential and linear thought, but also process and reticular thought. Drawing is the first child's writing form and it is an example of hyper-textual narration: it is narrative expression, but also expression of complexes of ideas.

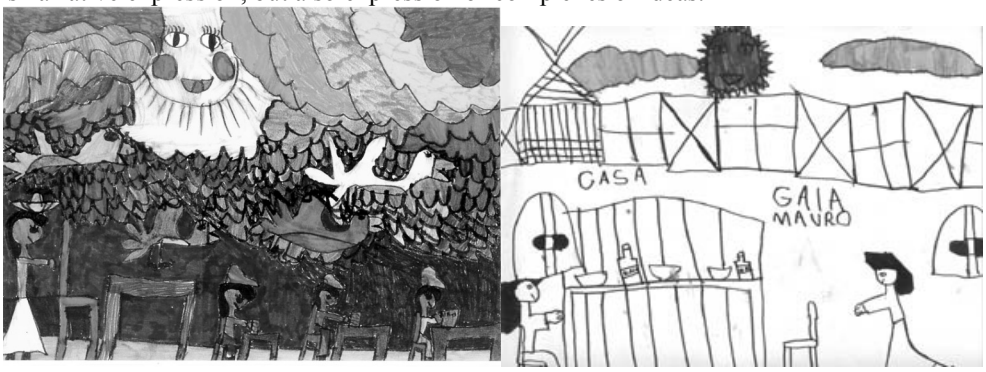


Fig.: "School–House" Example of an "hyper-textual" narration type: colours, words, full use of the space: front and back page Age: 5/6 years

The following examples illustrate how children go through the step described by Piaget (1926), where words keep for a long time for children a *meaning that is not only affective but almost magic or at least related to special actions* (4 years old), to the first spontaneous conceptual narrations, to the acquisition of composition rules of conceptual maps (5 years old).

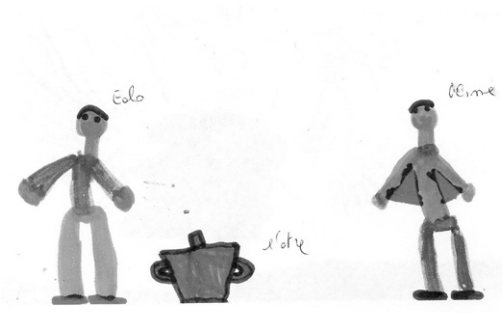


Fig.1. "Example of linear correlation-word concept"

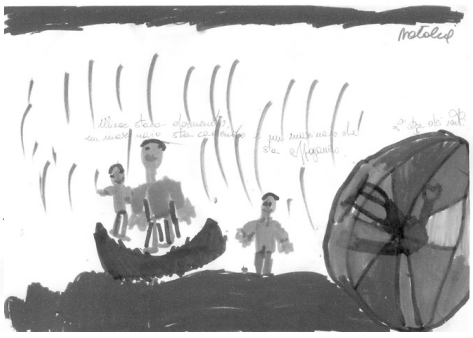


Fig.2 . "Example of complexes of ideas and potential concepts: use of metaphor"

These drawings made by five year's old children illustrate an Odyssey episode "*Eolo, the God of the wind, gives Ulysses the winds' goat-skin*"; The drawing no.1 shows Ulysses, Eolo the God of wind, and the winds' goat-skin: the interaction of word-concept is linear. Although the "goat-skin" is an huge container for water, wine, or oil and it's nowadays in disuse, we can notice that the first child knows it (fig.1); in the second case the drawing shows what

Piaget had already identified in the following sentence: "*children transform words in long lasting meanings which are not only effective, but almost magic or in any case related to special actions*" the drawing also shows what we conceive as the ability to understand complexes of ideas and elaborate them into combined meanings as a natural human mind process, together with the metaphoric use of language. They have a communication value related more to a semiotic than semantic type structure.

Fig.2: On the ship Ulysses is asleep, and a sailor is about to fall out the ship; in the sea a sailor is drowning ; on the right there is a special colorful wheel with a figure drawn at the centre as to represent the winds' goat-skin. Is quite clear that the child has never heard the word "goat-skin" and never saw the object, so in order to translate into image the complex of ideas suggested by the word "winds' goat-skin" he draws a big cloth parachute with colored segment (item that he had probably seen different time blowing in the wind) placing at the centre of it the anthropomorphic image that confirmed the "writing" as an authentic metaphor which is in my opinion perfect and poetic: in fact, what is better than a cloth parachute that stretches out, blows up and embraces the wind to represent the "winds' goat-skin?

The following drawings are "written stories" in absence of text. They are conceptual maps that are narrating experiences. Both maps No.1 and No.2 tell direct experiences. The first describes a didactic episode of observation: from a concept through a linear connection become visible the six concepts. The second tells an experience in science, concretely conducted, where is explain the correlation "plant-flower-fruit"; the connected-symmetric structure is concerning the logical-temporal interaction of the passages "plant-flower-fruit". The map No.3 is identified as the map "virus" ; it combines six lines of conceptual development: "virus"= get in-go out; attach-hit; live in; make sick (who?); provoke (symptoms); expel (cures): to these, 14 concepts are being added and connected in a correct way.

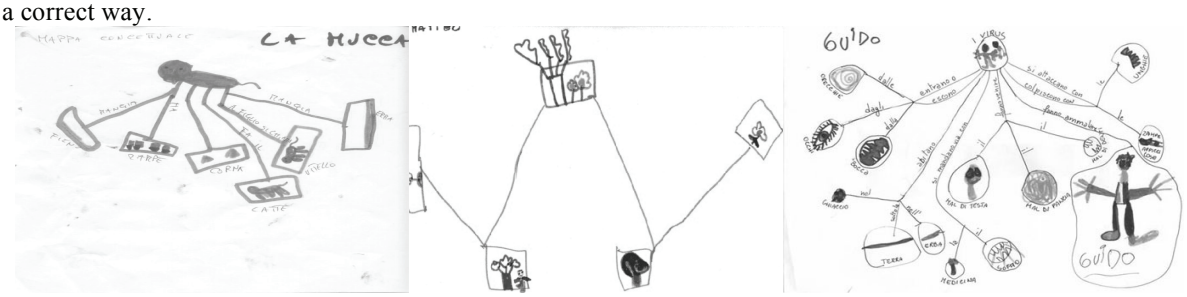


Fig.1"**Milch cow**"- connected structure Fig.2" **Tree**"- connected and symmetric structure Fig. 3 "**Virus**"- symmetric and branched structure

These maps show two thinking modes: the linear and sequential thought as mean and product of competences, and the reticular thought which puts in relation competences and turns them into culture. Conceptual maps reveal to be writing instruments: they transform complexes of ideas in organized narrations, they are detectors of writing as the organizing principle of human mind.

Furthermore, they show the reorganization of standard three-dimensional visual field – the appearance of perspective in different stages that depend on alphabetization progress – on the abstraction of language – on the psychological inwardness of writing as thought form.

They are very interesting in showing how some paradigmatic modalities are innate (connected structure, sequential structure, symmetric and branched structure, cyclic structure and semi-sequential structure): they visualize graphically the hierarchy order, the meaning attributed to words, the connection between concepts.

The concepts, expressed under a summarized form (words-concept), are *contained within a geometrical image* (a plane figure), which corresponds to a junction point; they are *linked* between each other *by lines*, which narrate this relation through *link-words*

5.2 Reading and writing learning in the computer era

Expression, representation, relation and critical thinking are "describers" (key words) of the species-specific "language faculty" that exercises the property of discrete infinity (Chomsky1988) through a syntactic decomposition of reality into basic meaning units. It is about a potentiality of combinations that allow human communication to

find forms, principles, and parameters and transform one's creative confusion into a powerful discernment of "language".

The following images are pages of an exercise-book belonging to a 5 year's old girl. It is an example of what we call LASS (Language Acquisition Support System) in relation to what Chomsky suggested about the terms of *legibility* imposed by other systems (ex.: *sense-drivers*) on generative processes. The first word that we intend to teach children is "Io"(English translation is. "I"). The choice is strategic:
1 – It's the word most used by a six year's old child in its life's egocentric phase; 2 – it's composed only by two characters (two vocals), but at the same time it has an accomplished sense (global method: language comprehension starting from the whole to the single characters); 3 – clear phonetic comprehension; 4 – legibility (visual system): the characters are graphemes (signs) made by vertical and horizontal lines ("orthoptic" facility of reading); 4 – reproductions of signs (hands drivers): vertical and horizontal lines to be reproduced on a 10 mm. grid (emotions' role: an enjoyed result of the child simplify the re-reading and the signs' memory); 5 – use of the stamped capital character (used by computer's keyboards, new alphabet); 6 – driving and linguistic games on a grid drawn on the ground to easily memorize the sense-drivers' routes to get to the expressive signs reproduction (emotions' role regarded to memory: happiness of learning).

The following figures show the importance of the vision (story) and of reading as analysis of the component elements of the sign-drawing (Fig.1and 6); their "reproducibility" arranged according to motor, modular, topological and rhythmic rules (Fig.2); the semantic and paradigmatic possibility of the sign-drawing (Fig.1, 2 and 3…); the "constructive" and concept consciousness of graphemes I and O (Fig 3 and 4);in the end, the drawing up of IO (engl. "I") (the beginning of the discrete infinity) (Fig. 5)

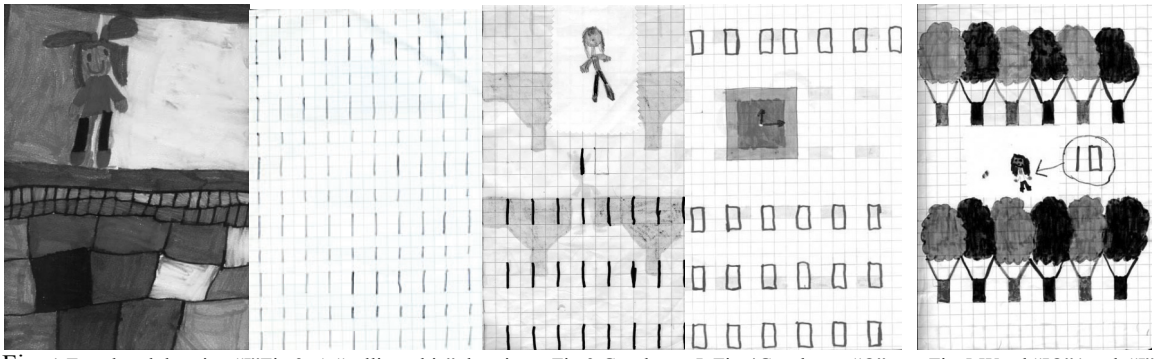
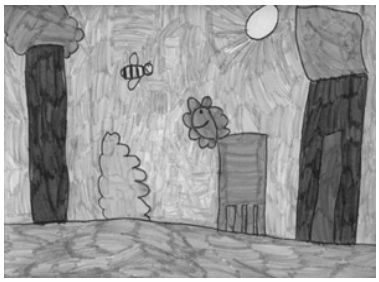
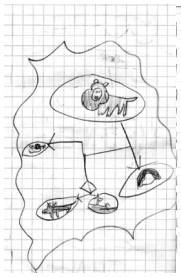


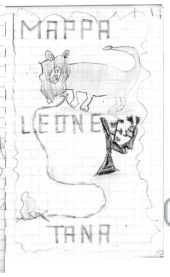
Fig. 1 Free-hand drawing "I"Fig.2 A "calligraphic" drawing Fig.3 Grapheme I Fig.4Grapheme "O" Fig.5 Word "IO"(engl. "I")

The last figure (number 5) is very important, because it conveys the conscious passage from sign-drawing to writing. The graphemes I and O are used to form the word IO (engl. "I"), and the "discovery" of writing is so important that it is marked and linked, with line and arrow, with her picture. The author has just written her first word, she knows only the two graphemes used, but she completes her story "inventing" communicative signs: the concept word "IO" is contained (recognized) in a graphic space, a line links it to another concept, the arrow shows the reading direction, that is, it identifies the starting point of thought and underlines the arrival that, in turn, can extend still further. At the same time the usual modalities of language (thought) appear: the linear and sequential one which makes it possible to write a word, and the reticular and processual one that transforms knowledge and competence into culture.

At this stage the use of computer can be started off, and on this support, too the children's outputs respond to two separate statutes: play (free and expressive drawing) and need (learning to do in order to be able to do). The screen turned out to be a very good sign memorization inductor, as well as the keyboard that, at this stage, plays the role of alphabet cards, with all the advantages of speed, easiness and fun. CmapTools has proved not only to be an excellent system of "memorization and electronic restoration of the knowledge based on conceptual maps" (Cañas by Novak 2001), but also a system to educate brains to exercise and increase the natural memory's potential. Basically CmapTools offers a concrete way of using the evocative power of visualization as an induced memory's activity (a well known power which had already been used and described by the ancient Greeks and Romans on which they based a truly art of memory). The figure is also evidence that starting children off on drawing maps is not only possible but it is a spontaneous writing modality in very young children, and that the passage to the use of software CmapTools is as much natural in only six year old children.







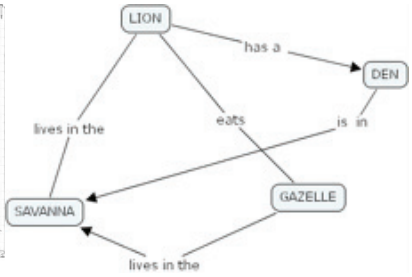


Fig 6 Drawing " The lion's story" Fig. 7 C- map "Lion" Fig 8 Map "The lion's den" Fig 9 Map "Lion" by CmapTools

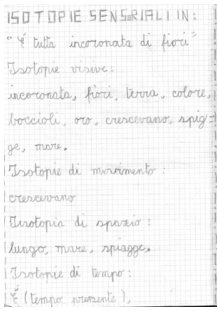
5.3 Writing and conceptual maps: an experience of semiotic approach to poetry text

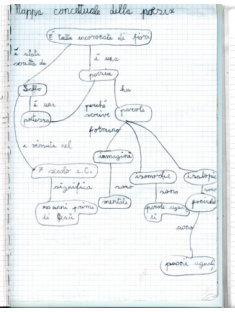
One of the "signals" that can announce problems in learning, and especially dyslexia, is the difficulty of association between sign and meaning, between instrumental capacity (when acquired) and cognition; it's an evident incapacity of relating *noesis- semiosis*, (intuition and competence, competence and culture). The semiotic analysis of text is used as a strategy to improve the LAD (Language Acquisition Device). In favoring the "underneath biological matrix that provides a situation in which the language improvement develops"- "a system of principles, conditions, rules, that are […] the essence of human language"(Chomsky1979), the child realizes the abstraction of determined peculiarities, their synthesis, their symbolization throughout a sign.

In a natural way the child is educated to acquire a scientific method to learn reading the reality beyond the *surface* and to codify messages more and more complicated. The following images illustrate some of the steps of our experience, fully reported, made with seven years' old children. We've used a poetical text, which for its nature is the closest to creative experience of the use of language.

1-Teacher's reading aloud of the poem →2- Empathic selection of some of the words- concept: flower, ground, sea, …; to start linguistic games: phonetics chains and of meanings →3-Writing of poetical text (chosen for its shortness and richness of images): *"it's all crowned of flowers the ground ,/ of multicolor flowers. / Golden buds were growing / along seashores. (SAFFO VII-VI B.C.).* (fig.1) → 4- Reading and first analysis of text to select concept-words and binding-words (list of words written on the board) →5- Selection of isomorphic (same words) and phonic isotopic (pieces of same words) (Fig.1) →6- Selection and list of sensorial isotopic: classification and grouping of visual isotopic, of movement, of space and phonic. (Fig.2) →7- Drawing up of the poem's concept map. (fig.3) → Drawing up of concept map of isotopic. (Fig.4) →8- Identification of the syntagmatic and paradigmatic axis→ 9- Drawing up of concept map of the word- metaphor (Fig.5)







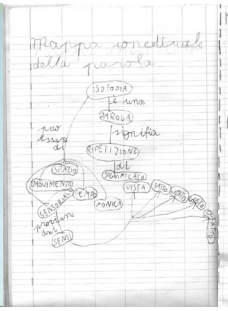




Fig 1 Fig 2 Fig 3 Fig 4 Fig 5

5.4 Competent use of hyper-textual writing

Our experience has confirmed that to acquire competence in any field it is necessary (most of the times) to use the active, iconic and symbolic modality which represents thought at the same time, according to a not pre-ordinate progression but that re-combines and re-places continuously, that is it mixes according the characteristics of the context and the intentions because for a child "*the voice of reality as for a mathematician is in the symbol's*

meaning" (R.Thom, 1988). The computer is the opening door for an immaterial place, of the context where children develop their potentiality*:* "the *apparent flow, a definite discontinuity: this non-phrase was not something that did not have the power of accessing the phrase, that was before the phrase: it was what is eternally and superbly out of the phrase"* (R. Barthes, 1975).

The computer is an instrument that lets the aggregation or the break-up of meanings and forms which children can use profitably with the help of an expert adult. What follows is only an home-page example of many hyper-textual works pupils of this Institute regularly produce as a conclusion of their formative processes: "Friend Country" (Age 8/9 years) on http://skat.ihmc.us:80 (ICVOLPONI-URBINO-IT); "Interaction" (9/10years) published on the web site www.lwparoledellascienza.it; "Journey in Scotland" (12 years) –available on www.icvolponi.it.

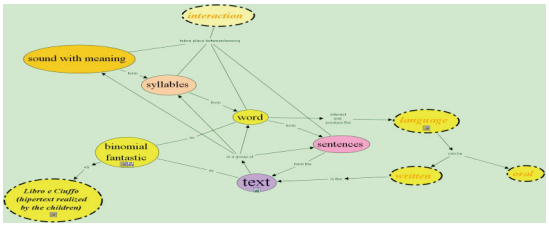


Fig. 1 Map: "Interaction- word"

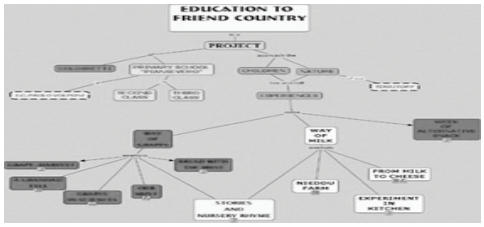


Fig. 2 Home page hypertext "Friend Country"

These "hyper-textual maps" show how *meaning attributions* and *language competence* (Novak, 1998) (the bases on which the knowledge formalization processes start and develop and make disciplinary knowledge be structured in a net of correlations) and together with their "rearrangement" of writing on the new multimedia software (3-7 years), become decisive for the scientific- organized thought development (8-12 years).

6 Summary

Based on our firm belief that language faculty, an instrument and output of species-specific intelligence, is a matrix of social interactions and sign systems (essential tools for communication and transmission of knowledge between generations), our educational method has found its natural modalities of communication and representation of knowledge and skills in the use of concept maps and CmapTools. This has brought to significant learning for all students, mainly for those, who had language problems when entering school. The positive and regular results strengthen our firm belief that language is matrix of sense and that evidence of meaning together with the extraordinary plasticity of the organ of knowledge are a valid instrument for prevention/rehabilitation of pathologies of knowledge such as dyslexia.

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8 References

Barthes R. (1975). *Il piacere del testo*, Torino: Einaudi, pp. 48-49.

Bruner, J. (1983). *Child's Talk: Learning to Use Language*, Oxford, O.U.P.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Chomsky A.N. (1965): *Aspects of the Theory of Syntax*, Cambridge, MA: M.I.T University Press.

Chomky A. N. (1971): *Problems of Knowledge and Freedom*, ed it. (2004): *Conoscenza e libertà*, Milano: Il Saggiatore, 15.

Chomsky N. (1979). *Rules and Representations.* Oxford: Basil Blackwell; it. ed. (1981), *Regole e rappresentazioni*. Milano: Il Saggiatore, p. 178.

Chomsky, N. (1988): *Language and Problems of Knowledge. The Managua Lectures,* Cambridge, Mass., The MIT Press; it. Ed. (1998) *Linguaggio e problemi della conoscenza*. Bologna: Il Mulino, 148,156-158.

Dawkins, R. (1976): *The selfish gene*, Oxford: University Press.

Eco U. (2005). *Ecco l'angolo retto* in *La bustina di Minerva.* Milano: L'Espresso n° 16.

Giombini, L. (2004). *From Thought Conceptual Maps CmapTools as a Writing System*, In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 273-280). Pamplona, Spain: Universidad Pública de Navarra.

Lynch K. (1964) *L'immagine della città.* Venezia: Marsilio.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press; it. ed. (1986) *Imparando a imparare*. Torino: Sei .

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations.* Mahweh, NJ: Lawrence Erlbaum Associates.

Piaget J. (1926). *The language and thought of the child*. New York : Harcourt Brace; it. ed.(1968) *Il linguaggio e il pensiero del fanciullo*. Firenze: Giunti, pp. 14-16.

Popper K.R., Lorenz K.(1989). *Il futuro è aperto.* Milano: Rusconi Editore, 32.

Salomon G. (1979). *Interaction of Media. Cognition and learning.* S. Francisco: Jossey - Bass Publisher.

Thom R. (1988*). Esquisisse d'une sémiophysique*. Paris, Inter Edition.

Vygotsky L. S. (1962): *Thougth and language*, by E. Hanfmann and G. Vakar. Cambridge, MA, MIT Press; it. ed.(1965) : *Pensiero e linguaggio*, Firenze, Giunti, 52, 62, 197.

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CONCEPT MAP AS VISUAL INTERFACE IN 3D DIGITAL DOSSIERS: IMPLEMENTATION AND REALIZATION OF THE MUSIC DOSSIER

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Abstract. This paper describes the implementation and realization of 3D digital dossiers, based on several case studies, which uses a concept map as navigation and visualization paradigm. The aims of these 3D digital dossiers are to provide intuitive navigation, efficient and effective search and detection of relational information structures, imposing immersive presentation of content and content related information by making use of 3D space and concept visualization. Altogether, the dossiers serve as a digital archive for domain experts and interested parties. The digital dossiers indicate that using a concept map to visualize and navigate through relational information structures is intuitive and effective.

1 Introduction

The increasing interest in accessing multimedia information and related 3D representation of information objects into an application has heightened the need for digital dossiers. The introduction of digital dossiers to accommodate such interest started as a master students project, based on the course Multimedia Casus lectured at the Vrije Universiteit[3], Amsterdam. In close collaboration with the Netherlands Institute for Cultural Heritage[4] (ICN) - a leading, independent knowledge institute for the preservation and management of so-called moveable cultural heritage -, digital dossiers where created to facilitate the need for accessing 2D and 3D information related to artists, artworks and installations on contemporary art.

It should be stressed that the digital dossier, according to our interpretation, can be seen as a digital archive which presents particular information about a specific topic in a specific way. We chose for the phrase digital dossier, and not for archive or library, to stress that our focus lies on presentational aspects.

Generally, the digital dossier consists of two main functional environments to allow for navigation and presentation of content. For navigation a concept map was developed that allows for detecting and choosing inter-related concepts, concept-related information, media recordings and 3D representations in a unified intuitive fashion. The concept map developed is considered purely as a proof of concept acting as navigational mechanism, and as a consequence of this focus, it is currently implemented as a concept graph. Relations shown between nodes in the concept map are not named but are intended to be directional, and can be regarded to be implicitly derived depending on the context of its destination node.

For the presentation of content, the advantages of 3D are used to allow for parallel presentation of text, audio, picture and video and to incorporate and present interactive 3D representations of information objects. Although both environments are visually and functionally different, it's aimed to be perceived as strongly related by the use of visual cues.

The aim of this paper is to provide experimental results that benefit research on using concept maps in user interfaces. In the following parts, we give more detailed explanation about our work: First, section 2 focuses on using concept maps in user interfaces and describes the different applications of the digital dossier. In section 3 requirements on the digital dossier are discussed, followed by section 4 where more detail is given about the implementation and realization process. Next, section 5 deals with the use of guided tours to present information and finally, in section 6, conclusions and future discussion are provided.

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2 Background and requirements

Using visual languages in communication to enhance understanding and to reduce cognitive load is well-known. Research indicates that certain visual languages like concept maps act as a working memory extension and enhances direct interpretation of information through pattern detection (Scaife et al., 1996). Such findings have led to using concept maps in knowledge representation in general.

The application of concept maps in education to enhance understanding can be considered effective (Novak et al., 1984) and even important. On the web for example, higher education promotes the use of concept maps as a way to visualize knowledge. The digital university[5], founded by Dutch universities, provides online information, examples and exercises for students to learn and use concept maps. Also in the field of Artificial Intelligence, concept maps where used to describe the semantic relationships in complex domains. As a navigation mechanism it is, for example used in the Visual Thesaurus[6].

When dealing with highly inter-related information structures in information systems, the notion of the concept map as a simple and intuitive visual form of knowledge representation has potential as user interface paradigm: interactively displaying structural relationships and context. Different visualizations have already been proposed to navigate hierarchical information structures (Schonhage et al., 2000). A well-known example of 3D information visualization is the 3D cone tree (Robertson et al., 1991). The 3D cone tree visualizes hierarchical structures and consists of cone objects. The motivation of using 3D over 2D cone trees is that 3D visualizations make optimal use of screen space and provides the opportunity to visualize larger hierarchical structures.

Due to the creation of the digital dossiers for and in collaboration with the Netherlands Institute for Cultural Heritage (as mentioned in the introduction), the following main user requirements where imposed:

The digital dossier should:

- Serve as an information source for domain experts,
- Represent highly inter-related information structures,
- Support the possibility to explore inter-related concepts,
- Present rich media recordings, and,
- Provide background information for the interested general public.

3 Applications and usage of digital dossiers

Based on the requirements with regard to the digital dossier, three applications for different domains where created and recently deployed:

- the Marina Abramovic dossier[7],
- the music dossier[8], and,
- the Jeffery Shaw dossier[9].

These three digital dossier applications are created with VRML (Virtual Reality Modeling Language), which allows for creating virtual worlds and present them on the web. The web publication makes it possible for the interested general public to access the digital dossiers worldwide and more easily.

The first digital dossier developed that used the concept map as information visualizer and navigational mechanism, is the *abramovic* dossier. The *abramovic* dossier is based on an interview with Marina Abramovic by which a transcription of the contents of the interview made by Michela Negrini, a student of media art at the University of Amsterdam, provided an interpretation as well as a categorization of the works of art. Given the

5 http://www.du.nl
6 http://www.visualthesaurus.com
7 http://www.few.vu.nl/~dossier05
8 http://www.few.vu.nl/~cvriel/casus05/mindossier
9 http://www.few.vu.nl/~casus05

material and the categories along which this material was classified, the concept map was developed to explore as an instrument for navigating the information space. The *abramovic* dossier has been presented and is well received at cultural events and institutes like the Institute for Time-based Arts - Montevideo[10] and ICN as a proof of concept.

With regard to conceptual domains, the Marina Abramovic and the Jeffery Shaw dossier focus on the artist, their artworks and artwork-related information. The music dossier contains information related to the domain of music. In the following parts, the music dossier will be used as a representative of the general functionality for all dossiers.

3.1 Visual navigation by concept map

In order to represent and support exploration of highly inter-related information, a concept map was created that visualizes the information into hierarchical structures which serves as a user interface for navigation. In more detail, the concept map has the following properties:

1. Parent-Child and non-taxonomical relationships visualized as a star structure: The concept map is implemented as a star-structured-hierarchy diagram that allows detecting relations between concepts and search for information. By star-structured we mean that relations between concepts are visualized by lines by showing a centered concept surrounded by related concepts (see figure 1).
2.

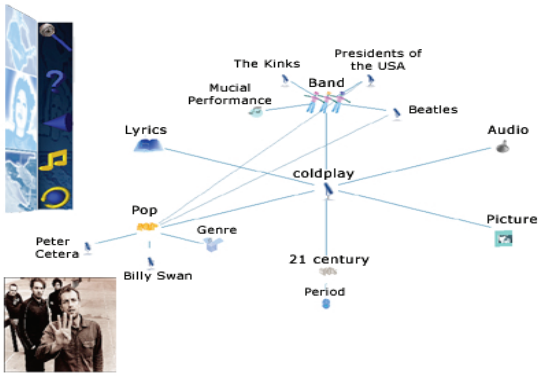


Figure 1: concept map visualizing hierarchy.

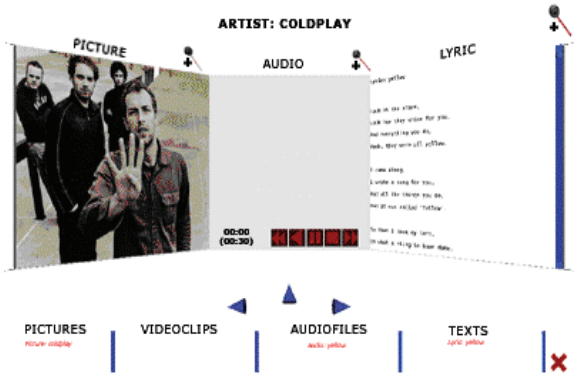


Figure 2: Content gadget with 3 panes visualizing media content

2. A three level deep view: The use of hierarchical structures can be compared with the 3D cone tree (Robertson & MacKinlay 1991), however, unlike the 3D cone tree, where the complete hierarchy is shown, only a subset of the hierarchy is visible - three levels deep - to avoid screen clutter. This view allows the user to browse through a large amount of data while displaying a limited number of items at a time.
3. Dynamically generated structure: A selected concept will be translated to the center of the screen, involving movement in the X and Y direction. It then becomes a parent node showing its children around it. So, the structure presented is determined by the user's choice.
4. 3D icons representing information types: Concepts shown in the concept map are represented by 3D icons. These 3D icons visualize a certain type of information. We distinguish between two main information types: categories and content. The content information type itself consists of different media types - text, pictures, audio and video - which are represented by different 3D icons.

To compensate for the lack of an overview where all information is shown at once, caused by the three level deep view, as noted above, the user can also use keyword search instead of concept map navigation.

10 http://www.montevideo.nl

3.2 Presentation of media content

To present media content in the dossier, a content gadget was developed which is activated when media in the concept map is selected for view, and has the following properties:

1. Three content windows: By making use of 3D space, media content can be presented simultaneously by using three content windows which can be selected to present text, pictures, audio and video. In our experience, the use of these three windows at the same time doesn't cause much visual distortion (see figure 2).
2. Focusing on particular content: Showing three content windows at once can lead to an information overflow. To deal with this, the user can focus on a particular window with a zoom option. This allows avoiding distraction from the other content windows.
3. Dynamic content display: By a drag-and-drop function, the user can customize his/her presentation view. This choice gives the user more freedom instead of being bounded to a fixed position of media presentation.
4. Internal linking: By selecting concepts represented by hyperlinks in text, the user is able to view their conceptual relations in the concept map.
5. Scroll-bar pane selection: Under the content windows are scroll-bar panes present which can contain more categorized media content to select for view.

3.3 Incorporation of 3D representations

Due to the use of the 3D technology VRML, 3D representations of real-world objects could be easily incorporated and presented in the digital dossier (see figure 3). The 3D environment demonstrates the interactive exploration of real-world objects which could benefit domain experts. By manipulating position and/or angle of objects, the user can get insight into which parts the object consists off.

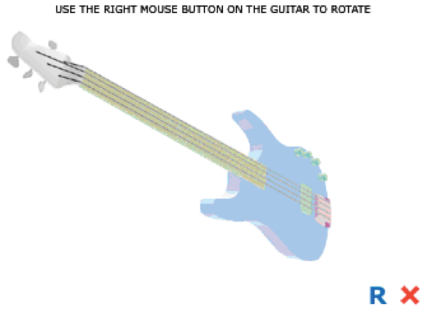


Figure 3: 3D representation of an electric guitar

At this point, we can only speculate how useful, in the perspective of Cultural Heritage, such a reconstruction can be as a tool for the conservator responsible for the re-installation, to play around with the presentation parameters, the positioning in space, the overall size, light and ambient effects.

3.4 Guided tours for automatic and focused presentations

When browsing through inter-related structures like in hypertexts, the end-user can experience some problems (Nielsen, 1990), like disorientation and quality of information retrieval. Directing the user's focus of attention, especially in complex inter-related structures, like the dossier where navigation is non-linear may prevent the user from becoming lost or confused. In this perceptive, guided tours can be used to automate user interaction and function as a narrative story telling facility.

Several types of guided tours have been implemented in the dossier to facilitate automatic and focused presentation of information:

- Conceptual guided tour - automatic and focused presentation of conceptual information by concept map.
- Technical and space related guided tours - automatic presentation of functional and/or technical aspects of real-world objects, allowing for manipulation of environmental parameters for exhibition purposes.

The realization of the conceptual guided tour will be discussed in more detail in section 5.3

4 Technical realization of the digital dossier

In short, the technical realization of the digital dossiers with regard to the concept map concerned two main parts: 1) the data structures, and, 2) visualization and animation of the concept map.

4.1 Data structures

To structure and categorize data into concepts and specify attributes (which outcomes are used by the concept map), a fixed number of record-like structures where created:

- Video information node – to display video fragments.
- Audio information node – to cast audio fragments.
- Picture information node – to show images
- Text information node – to present text
- Group node – to present a category

As stated above, these record-like structures are used by the concept map and contain attributes which includes common values like a unique identifier, a short –and a long name, the location of a 3D icon, connected unique identifiers from related nodes and a description. For some structures, like video, audio and text nodes, additional attributes are added: location of the source file, location of a preview image and height and width of the output presented. These nodes give access to the actual content.

The group node is used to create categories in the concept map where to nodes can be related. Below, an example of the structure is given:

```
GroupNode {
ID "BILLYSWAN"
shortName "Billy Swan"
urlIcon "models/solo_artist.wrl"
description [""]
connectedNodesIDs ["AudioBilly", “TextBilly”, “VideoBilly”, “PopGenre”, “InstrumentGuitar”]
}
Audio {
ID "AudioBilly"
shortName "let me help"
urlContent "audio/BillySwan.mp3"
description [""]
connectedNodesIDs ["BILLYSWAN"]
}
Picture {
ID "PictureBilly"
shortName "Picture: let me help"
urlContent "images/BillySwan/billy.jpg"
width 312
height 312
urlPreviewImage "BillySwan/billyswan.jpg"
heightPreviewImage 296
widthPreviewImage 296
description [""]
connectedNodesIDs ["BILLYSWAN"]
}
```

This piece of code illustrates the node connections as defined by the attribute 'conncetedNodesID's'. As shown, the group node is also connected to other nodes as well, which can be group nodes themselves or end nodes like audio or picture. Further more, the picture node contains some additional attributes that define width and height of the content itself and its preview image, as with video:

```
Video {
ID "VideoBilly"
shortName "Live performance clip"
urlContent "clips/billySwan.avi"
width 320
height 360
urlPreviewImage "images/previewImages/billy.jpg"
widthPreviewImage 220
heightPreviewImage 140
description [""]
connectedNodesIDs ["BILLYSWAN", "videoClips"]
}
```

4.2 Visualizing and animating the concept map

Each navigational action, whether by mouse clicks, filtering or keyword search, causes the concept map to change into a new state. This process of change includes determining the center node (which is the concept selected and placed in the center of the screen) and its related nodes (which are its related concepts), visualizing them star-structured wise and animating their transitions to a final position.

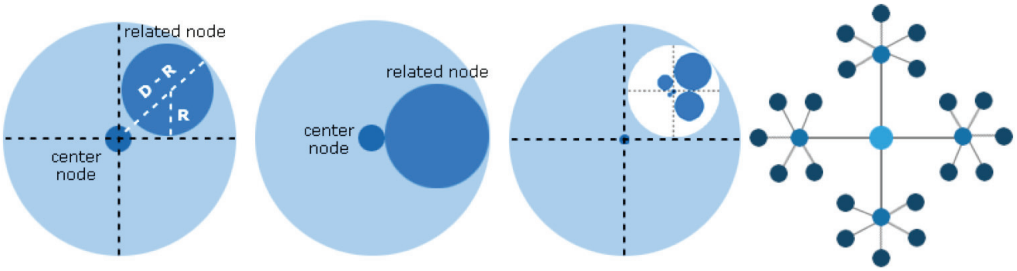


Figure 4: radius related node **figure 5**: minimum distance **Figure 6:** indirect-related nodes **Figure 7:** three level deep view

4.2.1 Drawing the node structure

When the center node and related nodes are determined, the new concept map state is computed as positions on a 2D plane. The process can be described in 5 steps:

1. *Step 1 – centralization center node*: First the center node is placed in the center of the available space. This node represents the information the user is focusing on.
2. *Step 2 - available radius center node*: Next, the available radius for the center node is set. This radius must be larger than the space taken in by the center node itself otherwise there is no room for drawing the related nodes.
3. *Step 3 – available radius related nodes*: In this step, the radius that is available for each related node (direct related) of the center node is computed. First, the circle around the center node, as computed in step 2, is divided into sectors. The number of sectors used is equal to the amount of related nodes. The space available for a related node is the circle that fits inside a sector, as shown in figure 4. However, the circle around the related node may not intersect with the center node; this puts a minimum on the distance from the center node to the related node. If this is the case, the circle available for the related node is decreased to not intersect with the center node (i.e. the radius is derived from the minimum distance and the available space (radius) of the center node), as shown in figure 5.
4. *Step 4 – actual radius related nodes*: The three level deep view, as implemented into the concept map, allows the related nodes to have related nodes themselves. This leads, from the center node perspective, to indirect-related nodes. In this step, the actual radius used by the related node will be computed based on the number of

nodes it is related to. For each of the indirect-related nodes, the distance it will be placed from the related node is computed. These nodes must not intersect each other, so they are arranged around the related node, as depicted in figure 6. The distance to the related node is equal for each surrounding node and has equal sector size to be drawn in. The distance between an indirect-related node and the related node is taken as small as possible such that the indirect-related node just hits the borders of the sector. In case the related node and indirect-related node would intersect, they will be put next to each other. If the required radius of the related node exceeds the available radius, the available radius is taken as the required radius. Also the related node and the indirect-related nodes will be scaled down to fit inside its available radius.

5. *Step 5 – position nodes in concept map:* In this last step, the position of all the nodes in the concept map are realized as computed in the pervious steps. Figure 7 illustrates an arrangement of the nodes implemented as a star-structured concept map.

4.2.2 Animating state transitions

When a node (other then the center node) in the concept map is selected, the concept map goes to a different state: the selected node becomes the new center node and is placed in the center of the space. This change is animated and shows the transition of the old to the new state. Nodes that are also needed in the new state, move by interpolation to their new locations. Nodes that are no longer needed disappear from the screen with a fade-out effect, where new nodes that are needed appear with a fade-in effect.

4.2.3 Further details

Because of the inter-related data present in the dossier, multiple occurrences of the same nodes in the concept map are possible. This happens, for example, when in a particular state a concept is an indirect-related node of two or more related nodes. In such cases, the indirect-related node is only drawn once by the following rule: if a node is already drawn for its related node, the other possible locations will be left open. As mentioned earlier, the center node is drawn first, then the related nodes and at last the indirect-related nodes. As a result, most open locations will be around the related nodes.

To indicate relationships, lines are drawn between the nodes. If a node has a relation to a node that is direct, an apparent colored line is drawn, if the node is indirect related, a non-apparent colored line is drawn; because the node was already elsewhere drawn.

4.3 Automatic conceptual navigation by a guided tour

Due to the amount of relational data and complexity of the conceptual structure, a conceptual guided tour was developed that assist the user in informational retrieval by directing focus of attention (see section 4.4).

This guidance - automating user interaction by a time-based sequence of events that activates navigational functions - uses the concept map as a narrative story facility to present information of interest. This allows the user to explore conceptual relations and related media or 3D representations by automation in a defined conceptual context. It is believed to have the following advantages:

First, it can support information retrieval:

- Effectively - presenting all relevant information in a narrative order given a its conceptual context, and,
- Efficiently - avoiding time consuming manual navigation finding objects of interest (without getting lost or confused).

And secondly, an interesting possible feature can be to support information analysis by presenting how to interact with real-life objects.

As concerns the implementation, the guided tour program consists of several input and output channels by which it communicates with functions present in the digital dossier. In order to automate user interaction, the guided tour program fires events with specific values at specific pre-defined times to activate functions by the input and output channels. By calculating the current time of when the guided tour is activated, it is determined based on a set

of rules when (at which time after activation of the guided tour) an event is allowed to be fired. In the standard interaction these events are fired by user mouse clicks or key strokes.

5 Conclusion

This paper began with the premise that using a concept map as a visual interface may provide intuitive navigation when dealing with highly inter-related information structures. In practice, digital dossiers where created that use a concept map - implemented as a star-structured diagram where the presentation of the structure is dynamic - as a visual interface where the presentation of content is separated from navigation but still indicating a strong relation between them. In addition, to assist the user in navigation and search, several guided tours where created to enhance information retrieval and analysis. So far, initial user feedback on the digital dossiers looks very promising for using the concept map as a navigation paradigm. Because this study cannot of course be viewed as conclusive, evaluations focused on quantitative results needs to be conducted to get a more accurate view. Also deploying the digital dossiers in other applications for the real world may reveal further issues for research.

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- Montevideo: Bart Rutten and Gaby Wijers.

References

Nielsen, J. *Hypertext and Hypermedia*, Academic Press, San Diego, Calif., 1990. pertext programming system.

Novak J. and Gowin D. B., *Learning How To Learn*. Cambridge, UK: Cambridge University Press, 1984.

Robertson G.G. and MacKinlay J.D. (1991), *Cone trees: animated 3D visualizations of hierarchical information*, Proc. of the SIGCHI Conference on Human factors in computing systems: Reaching through technology, 189 194, New Orleans, Louisiana, United States, March 1991.

Scaife M. and Rogers Y., *External cognition: how do graphical representations work*?, International Journal of Human-Computer Studies, Volume 45 Issue 2, august 1996.

Schonhage, B., van Ballegooij, A., Eliens, A. (2000), *3D gadgets for business process visualizations*, Proc. of the Fifth symposium on Virtual reality modeling language (Web3D-VRML), 131 - 138, Monterey, California, United States, February 2000.

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CONCEPT MAPPING AS A MEANS FOR BINDING KNOWLEDGE TO EFFECTIVE CONTENT-AREA INSTRUCTION: AN INTERDISCIPLINARY PERSPECTIVE

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Abstract. The recognition of conceptual knowledge as a critical element in effective content-area instruction has been advanced by the development of concept mapping applications to instruction. This paper broadens awareness of how concept mapping can serve as a basis for linking instructional strategies that when combined with concept mapping form an instructional system teachers are able to use to improve the quality of student content-area understanding. Presented is a knowledge-based content-area teaching model incorporating interdisciplinary perspectives that provides the means for teachers' use of concept mapping in conjunction with research-based instructional strategies to improve the effectiveness of content-area instruction.

1 Introduction

The role of conceptual knowledge and the structural representation of such knowledge is becoming recognized increasingly as a critical element of effective content-area instruction (Romance & Vitale, 1997, 1999; Vitale & Romance, 2000, 2006). A leading dynamic force in this initiative has been the development of concept mapping applications to instruction coupled with the accessibility of computer-supported concept mapping tools (see Novak & Canas, 2006). In their recent article, Novak and Canas discussed the role of concept mapping in cumulative meaningful learning and different uses of concept mapping by teachers and students to enhance in-depth content understanding.

The purpose of this paper is to broaden awareness of how concept mapping can serve as a core element for linking together (i.e., "binding") other instructional strategies in order to build an effective instructional system that teachers are able to use to improve the quality of student content-area understanding. In doing so, the paper describes a knowledge-based content-area teaching model in which concept mapping is the key element but which also reflects several interdisciplinary perspectives. The first perspective considers meaningful understanding as a form of expertise (see Bransford et al, 2000) and emphasizes the importance of conceptual organization and accessibility as important characteristics of prior knowledge on which experts depend. The second perspective follows a knowledge-based approach to instruction which requires all instructional and assessment activities to be linked explicitly to a representation of the logical structure of the content discipline to be learned. The third perspective is an instructional systems view that research-based initiatives for improving content-area instruction must be sufficient to impact student performance and engineered so that teachers are able to use them with fidelity. Considered together, these three perspectives are suggestive of approaches to content-area instruction that broaden teachers' use of concept mapping in instruction.

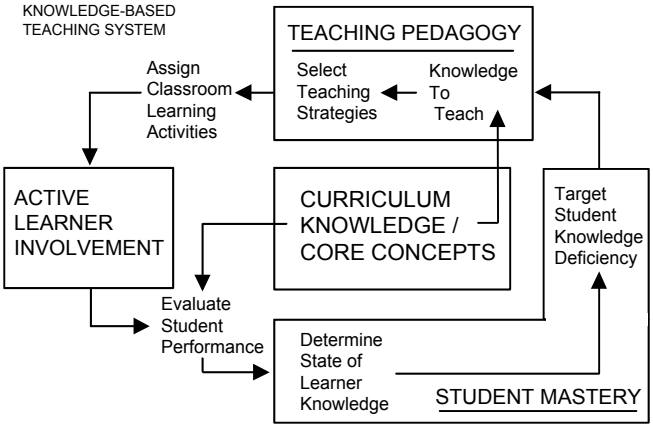


Figure 1. Knowledge-based intelligent tutoring system.

2 Cognitive Science Foundations of Knowledge-Based Instruction Models

The distinguishing characteristic of knowledge-based instruction models is that all aspects of instruction (e.g., teaching strategies, student activities, assessment) are related explicitly to an overall design framework that represents the logical structure of the concepts in the subject-matter discipline to be taught. In considering this design characteristic as a key focus for meaningful learning, knowledge-based instruction is best illustrated by the original architecture of computer-based intelligent tutoring systems (ITS) developed in the early 1980's (e.g.,

Kearsley, 1987). As Figure 1 shows, in ITS the explicit representation of the knowledge to be learned serves as an organizational framework for all elements of instruction, including the determination of learning sequences, the selection of teaching methods, the specific activities required of learners, and the evaluative assessment of student learning success. In considering the implications of knowledge-based instruction for education, it is important to recognize that one of the strongest areas of cognitive science methodology focuses on explicitly representing and accessing knowledge (e.g., Luger, 2002; Kolodner, 1993, 1997; Sowa, 2000).

The research foundations of knowledge-based instruction models are consistent with well-established findings from cognitive science. These cognitive science perspectives were reviewed in a recent report by the National Academy Press, *How People Learn*, edited by Bransford et al (2000). In doing so, Bransford et al stressed the principle that explicitly focusing on the core concepts and relationships that reflect the logical structure of the discipline and enhancing the development of prior knowledge are of paramount importance for meaningful learning to occur (see also Schmidt et al, 2001). Closely related to this view is work by Anderson and others (e.g. Anderson, 1992, 1993, 1996, Anderson & Fincham, 1994; Anderson & Lebiere, 1998, Anderson, Bothell et al, 2004, Anderson, Douglass, & Qin, in press) who distinguished the "strong" problem solving of experts as highly knowledge-based and automatic from the "weak" strategies that novices with minimal knowledge are forced to adopt in a heuristically-oriented, trial-and-error fashion. Also directly related are key elements in Anderson's (1996) ACT cognitive theory that (a) consider cognitive skills as forms of proficiency that are knowledge-based, (b) distinguish between declarative and procedural knowledge (i.e., knowing about vs. applying knowledge), and (c) identify the conditions in learning environments that determine the transformation of declarative to procedural knowledge.

Other research supporting the importance of prior knowledge stresses that the conceptual understanding and use of knowledge by experts in application tasks (e.g., analyzing and solving problems) is primarily a matter of accessing and applying prior knowledge (see Anderson, 1992, 1993; Kolodner, 1993, 1997) under conditions of automaticity. As characteristics of learning processes, the preceding emphasizes how extensive amounts of varied experiences (i.e., practice) focusing on knowledge in the form of the concept relationships to be learned are critical to the development of different aspects of automaticity associated with expert mastery in any discipline.

3 Considering Content-Area Comprehension from a Knowledge-Based Perspective

An important implication from the Bransford et al (2000) book supported by a wide variety of sources (e.g., Carnine, 1991; Glaser, 1984, Kintsch, 1998; Romance et al, 2004; Vitale & Romance, 2000, 2006) is that curriculum mastery is best considered a form of expertise and that student conceptual mastery of academic content should reflect how experts perceive the discipline. In this regard, emphasizing the in-depth understanding of core concept relationships within a discipline is a critical element of general comprehension and, by inference, of comprehension tasks that involve meaningful learning as well. In fact, the knowledge-based perspective of meaningful comprehension presented by Bransford et al (2000) would suggest the nature of meaningful comprehension in both general environmental learning and reading settings are equivalent, with the exception that the specific learning experiences associated with reading comprehension are text-based.

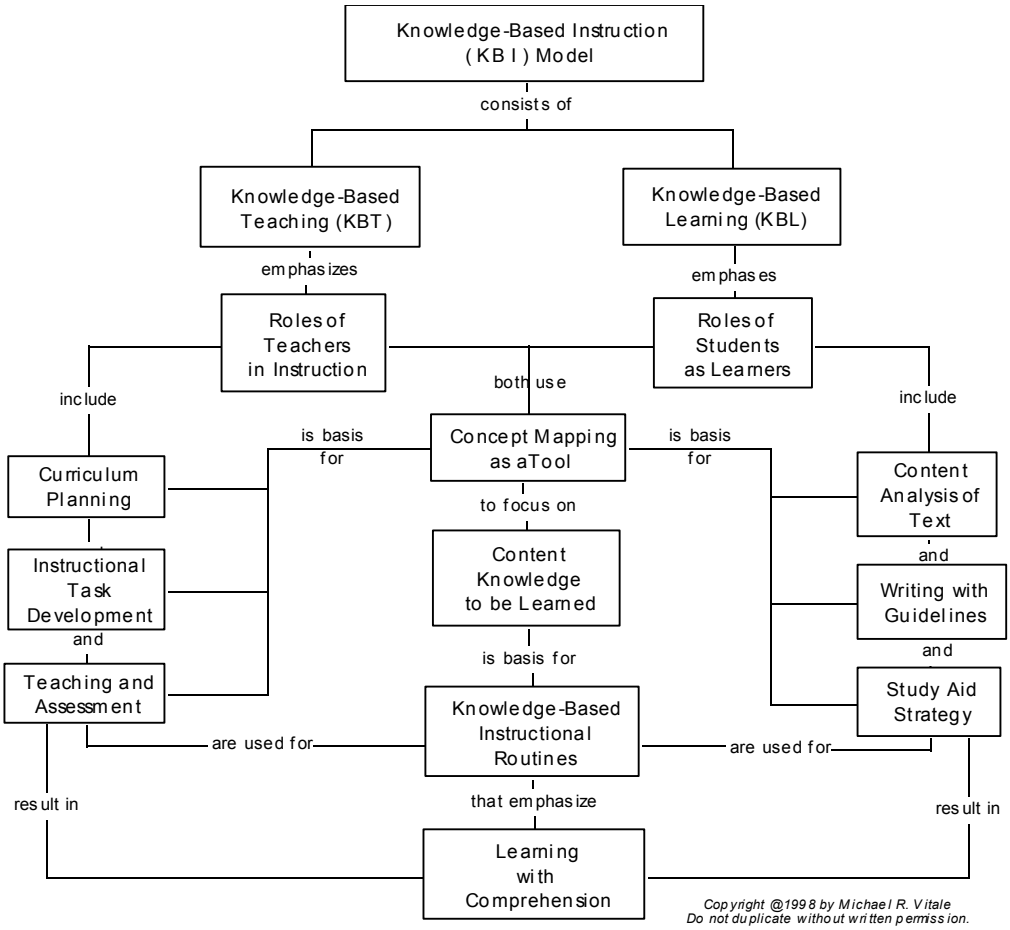


Figure 2. Overview of the Knowledge-Based Instruction (KBI) Model using concept mapping as a core component.

Figure 2 shows the framework of a Knowledge-Based Instructional (KBI) model that evolved over a 10 year period beginning with a series of research studies in grades 3-4-5 (see Romance & Vitale, 2001; Vitale & Romance, 2006). These studies repeatedly found that embedding reading within in-depth science instruction in daily 2-hour instructional time periods resulted in greater achievement growth in both content-area understanding of science as well as reading comprehension. As the research program evolved, the instructional model used in grades 3-4-5 (*Science IDEAS*) began to place greater emphasis on teachers and students using propositional concept maps as a knowledge-representation tool to organize and represent the conceptual relationships they were learning (see Novak & Gowin, 1984). Subsequently, as the research agenda expanded to other instructional levels ranging from middle school (e.g., Vitale & Romance, 2006) to post-secondary instruction (e.g., Haky et al, 2001; Romance, Vitale et al 2000), in which the use of propositional concept mapping was expanded to include having the concept map serve as an instructional guide (e.g., post-secondary biology, chemistry, physics faculty used concept mapping to engender meaningful student learning). In outlining the architecture of the knowledge-based instruction model (KBI), Figure 2 illustrates how concept mapping provides a knowledge-based focus for all elements of instruction. Specifically, the left branch focuses on the use of concept maps by teachers and the right branch on the use of concept maps by learners. The specific form of concept mapping used in the KBI model was adapted from Novak and Gowin (1984) and, in general, the efficacy of concept mapping as an instructional support tool is well-established in a variety of content areas (e.g., BouJaiude & May, 2003; Brown, 2003; DiCecco & Gleason, 2002; Gahr, 2003; Romance & Vitale, 1999; Sen, 2002) and is an active area of development (e.g., Jacobs-Lawson & Hershey, 2002; Nicoll et al, 2001; Novak & Canas, 2006).

In using the KBI model, propositional concept maps are used to represent knowledge whose units consist of objects (usually concept labels enclosed in boxes) and links denoting labeled relationships (typically consisting of verbs). In building propositional concept maps, two major enhancements of Novak's original procedure are emphasized by the KBI model. The first is that each set of linked objects forms (or approximates) a simple complete

sentence (e.g., OBJECTS expand when HEATED, ENERGY FORMS include …). The second is that propositional concept maps are organized hierarchically, with core concepts (or big ideas) at the top, subordinate concepts below, and specific examples (if any) on the bottom. Figure 3 illustrates a propositional core concept map developed from the content in an earth science program.

Keeping Figure 3 in mind, the KBI model shown in Figure 2 represents teachers' use of propositional concept maps to identify core concepts to be taught and then, subsequently, to plan instruction that is as conceptually coherent as possible. In developing such concept maps, teachers are encouraged to use submaps to represent increasing levels of curriculum detail. The second teaching component of the model includes three different strategies for enhancing instruction: (a) use of concept maps as visual support for

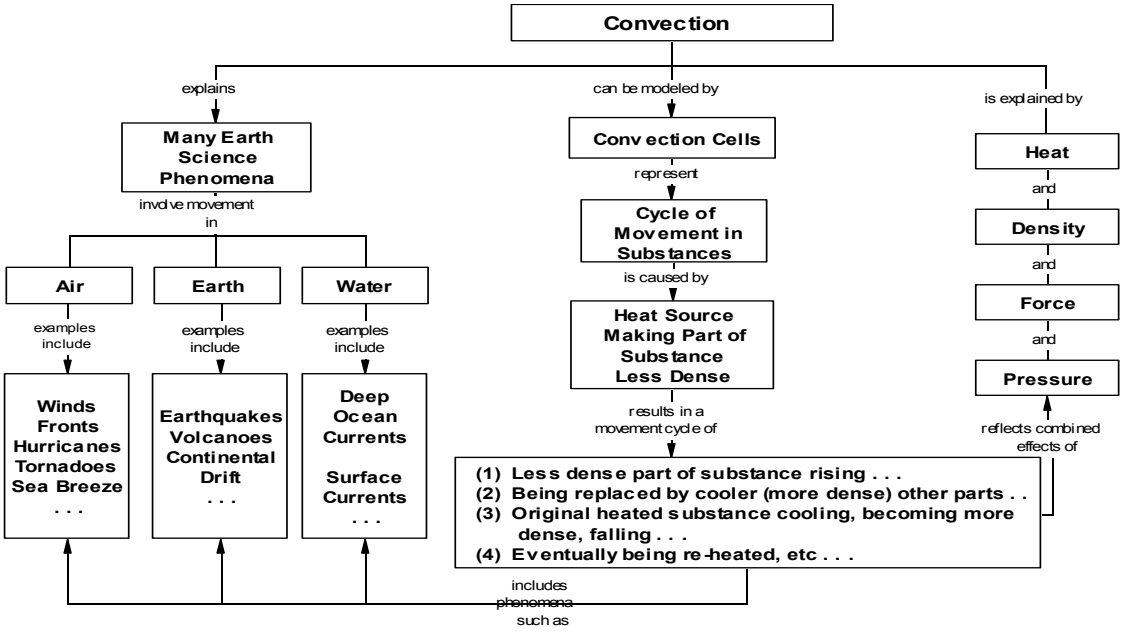


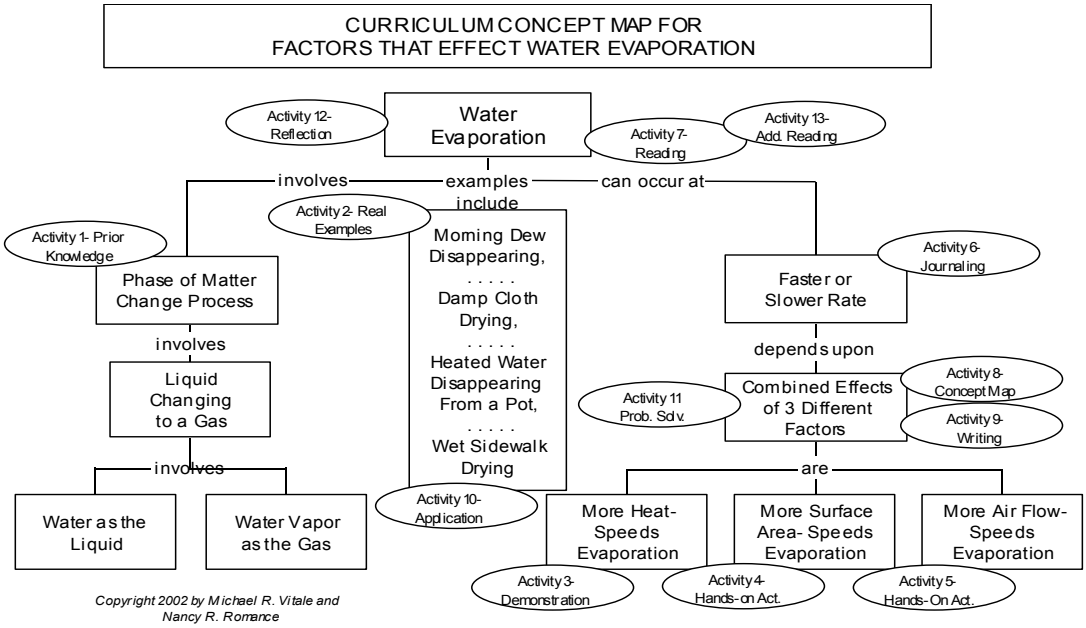
Figure 3. A propositional concept map for convection. The map provides a conceptual framework for instructional planning and for student meaningful understanding.

students during instruction, (b) use of concept maps as a framework for assessment, and (c) use of concept maps as a referential framework to motivate student learning. The third KBI teaching component includes advanced teacher skills based on instructional design principles (e.g., Allen et al, 2004; Dick et al, 2005; Engelmann & Carnine, 1991) for generating content-area instructional activities that require applications of the knowledge represented in the concept maps. Logically, this third teaching component represents an instructional transformation of the declarative knowledge represented in propositional concept maps into procedural (or applied conceptual) knowledge. In the KBI model, these activities consist of instructional enhancements used by teachers for modeling (or demonstrating) knowledge applications, for guided or independent student practice, or for authentic assessment. Thus, within the KBI model, the process of generating application activities can be used either for authentic assessment or as contexts for teaching concept applications or dynamic concept relationships (e.g., in science, a substance can be made to expand by heating it). Within the framework of the KBI model, Figure 4 illustrates the use of a propositional concept map as a curricular guide for insuring the instructional coherence of a unit on evaporation at the mid-elementary school level.

The purpose of the three learner (vs. teacher) KBI components is to focus student learning on the core concepts and concept relationships in the curriculum content. In the first component, for example, students use a knowledge-focused reading comprehension strategy to identify the core concepts and relationships in their textbooks and related reading materials followed by construction of a propositional concept map that enhances comprehension. And, although educational text materials might be expected to present coherently-organized information, most content textbooks do not do so (e.g., see Holliday, 2002, 2003; McNamara et al, in press). In the second component, students use concept maps to guide their writing and composition within the content domain. And, in the third component,

students learn to use concept maps as study guides that represent cumulative curriculum knowledge. Again, although the components could be applied separately (if teachers supply the appropriate concept maps), the logical use of the three is for teachers to begin by introducing students to the first component, then the second, and then the third.

In considering the KBI model, all of the components are clearly related through propositional concept mapping, which, in turn, reflects and focuses on the conceptual knowledge to be learned. By using concept mapping as a form of linkage, teacher and student components are able to complement each other. At the same time, teachers using the



KBI model have a great deal of flexibility in terms of which components of

Figure 4. Simplified illustration of a propositional curriculum concept map used as a guide by teachers to plan a sequence of knowledge-based instructional activities

the model to use to enhance their classroom instruction. In general, research findings in post secondary settings for undergraduate instruction in chemistry and biology (e.g., Haky et al, 2001; Romance, Vitale et al 2000) have been supportive of the feasibility and effectiveness of the KBI model for enhancing content-area student learning. In particular, results of this KBI research initiative have shown a substantial enhancement of student academic achievement in college chemistry and beginning biology, areas that typically suffer high rates of student dropouts or failures.

4 Engineering an Amplified KBI Model for Teacher Use

Although the KBI model (see Figure 2) was research-grounded and conceptually sound, only the parts directly involving concept mapping were feasible to implement on a large scale. Rather, the advanced instructional components of the model were difficult for teachers to implement in a consistent fashion without extensive and continuing support. What was needed, in fact, was an alternative model that included all of the key elements of the KBI model feasible to implement and added the other implicit KBI elements in a form that was more natural for teachers to incorporate in instruction.

Figure 5 shows the architecture of the amplified KBI model. As Figure 5 shows, the strategies are grouped into two categories (curricular/conceptual, instructional enhancements) that together form a modular-oriented instructional system. In the system, while all of the components are complementary, each component could also be implemented independently as an enhancement to regular instructional practices. In addition, as components comprising a professional development system, they are orderable with regard to the sequence of introduction (and groups) for content-area teachers.

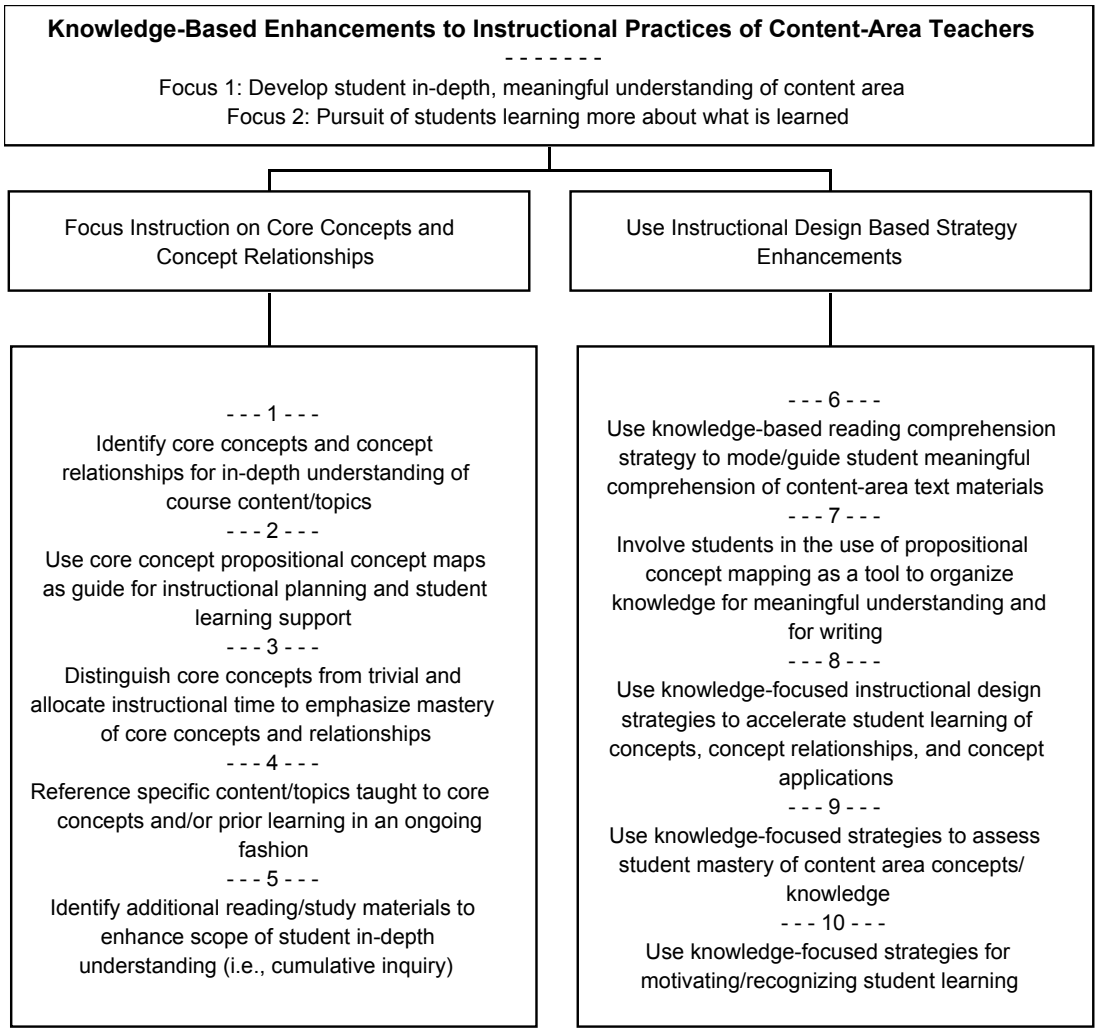


Figure 5. Amplified KBI model restructured to operate as modular enhancements to the instructional practices of content-area teachers. Note that concept mapping (#2), (#7) are used to bind other instructional enhancements to teaching within a knowledge-based instructional systems framework.

Within a professional development setting, the sequence of the initial group of amplified KBI components are: (#4) Referencing specific concepts taught to core concepts and/or prior learning in an ongoing fashion, (#6) Using a knowledge-focused reading comprehension strategy to model and guide student meaningful comprehension of content-area text materials (this strategy also emphasizes students actively relating what they are reading to prior knowledge), (#5) Identification of additional reading/study materials to enhance (#6) Using a knowledge-focused reading comprehension strategy to model and guide student meaningful comprehension of content-area text materials (this strategy also emphasizes students actively relating what they are reading to prior knowledge), (#5) Identification of additional reading/study materials to enhance student understanding, and (#2) Using propositional concept maps as a guide for instructional planning and student learning support.

The second group of amplified KBI components addressed in professional development are: (#7) Involving students in the use of propositional concept maps as a tool to organize knowledge for meaningful understanding, (#1) Identification of core concept and concept relationships necessary for in-depth understanding of the course content, and (#9) Using knowledge-focused instructional strategies to assess student mastery of concept area conceptual knowledge.

Finally, the third group of KBI components addressed in professional development are: (#8) Use instructional design strategies to accelerate student initial learning of concepts, concept relationships, and concept applications, (#3) Distinguish core concepts from trivial and allocate instructional time to emphasize mastery of core concepts and relationships, and (#10) Use knowledge focused strategies for motivating/recognizing student learning.

In interpreting the amplified KBI model, items #1, #2 , #4 ,#5, and #7 were included in the original model, while items #3, #6, #8, #9, and #10 represent a significant detailing of enhancements- which would either fit logically within the lower-left (Teaching and Assessment) box on the original KBI model (#3, #8, #9, #10) or as an enhancement to the student concept mapping box (#6). The resulting revision, therefore, explicitly specifies teacher activities in the form of strategies that research (e.g., Engelmann & Carnine, 1991; Vitale & Romance, 2006) has shown significantly enhance the effectiveness of content-area instruction.

5 Summary and Implications of the Amplified Knowledge-Based Model

As designed (i.e., engineered), the amplified KBI model has the potential to improve the quality of instruction in any content domain for which conceptual coherence is a requirement for in-depth, meaningful understanding. In doing so, it represents a significant enhancement to instructional strategies that focus on concept mapping alone. Although in the amplified KBI model, concept mapping as a knowledge explication technique is the key element, the additional enhancements in the amplified KBI model provide a means through which concept maps (or mapping) can bind these enhancements to the operational elements of teaching considered from an instructional systems point of view.

Presently, the amplified KBI model is being implemented with middle school science teachers as part of a multi-year NSF-funded project designed to study the means for accelerating student science achievement in grades 3-8 in preparation for high school. Through the present, teachers have responded positively to the model and are implementing the different components in conjunction with their introduction and follow up in project professional development sessions. The project is assessing both the feasibility and impact of the amplified KBI model on student content-area achievement at the upper elementary and middle school levels.

References

Allen, B. S., Otto, R. G., & Hoffman, B. (2004). Media as lived environments: The ecological psychology of eductional technology. (pp. 215-241). In D. H. Jonassen (Ed.). *Handbook of research on educational communications and technology.* Mahwah, NJ: Erlbaum.

Anderson, J. R. (1996). ACT: A simple theory of complex cognition. *American Psychologist*, 51*,* 335-365.

Anderson, J. R. (1993). Problem solving and learning. *American Psychologist*, 48*,* 35-44.

Anderson, J. R. (1992). Automaticity and the ACT theory. *American Journal of Psychology,* 105*,* 15-180.

Anderson, J. R. (1987). Skill acquisition: Compilation of weak-method problem solutions. *Psychological Review*, 94, 194-210.

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review*, 89, 369-403.

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y . (2004). An integrated theory of the mind. *Psychological Review*, (4). 1036-1060.

Anderson, J. R., Douglass, S. & Qin, Y. (in press). How should a theory of learning and cognition inform instruction?. In A. Healy (Ed.) *Experimental cognitive psychology and it's applications*. American Psychological Association; Washington, D. C.

Anderson, J. R., & Fincham, J. M. (1994). Acquisition of procedural skills from examples. *Journal of Experimental Psychology,* 20*,* 1322-1340.

BouJaiude, S., & May, A. (2003). *The effect of using concept maps as study tools on achievement in chemistry.* Paper presented at the Annual Meeting of the National Association of Research in Science Teaching, Philadelphia, PA.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn.* Washington, DC: National Academy Press.

Brown, D. (2003). High school biology: A group approach to concept mapping. *American Biology Teacher*, 65, 192-197.

Carnine, D. (1991). Curricular interventions for teaching higher order thinking to all students: Introduction to a

special series. *Journal of Learning Disabilities, 24(5),* 261-269.
Dick, W., Cary, L., & Cary, J. L. (2005). *The systematic design of instruction.* NY: Allyn & Bacon
Engelmann, S., & Carnine, D. (1991). *Theory of instruction.* Eugene, OR: ADI Press.
Gahr, A. A. (2003). Cooperative chemistry: Concept mapping in the organic chemistry lab. *Journal of College Science Teaching,* 32, 311-315.
Glaser, R. (1984). Education and thinking: The role of knowledge. *American Psychologist,* 39*,* 93-104.
Haky, J., Romance, N., Baird, D., Louda, D., Aukszi, B., Bleicher, R., et al. (2001, March). *Using multiple pathways to improve student retention and achievement in first semester chemistry*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO.
Holliday, W. G. (2002). Selecting a science textbook. *Science Scope.* 25, 16-18.
Holliday, W. G. (2003). Methodological concerns about AAAS's Project 2061 Study of Science Textbooks. *Journal of Research in Science Teaching,* 40, 529-534.
Jacobs-Lawson, J. M., & Hershey, D. A. (2002). Concept maps as an assessment tool in psychology courses. *Teaching of Psychology,* 29, 25-29.
Kearsley, G. P. (Ed.). (1987). *Artificial intelligence and instruction: Applications and methods*. NY: Addison-Wesley.
Kintsch, W. (1998b). The role of knowledge in discourse comprehension: a construction-integration model. *Psychological Review,* 95, 163-182.
Kolodner, J. L. (1997). Educational implications of analogy: A view from case-based reasoning. *American Psychologist,* 82, 57-66.
Kolodner, J. L. (1993*). Case-based reasoning.* San Mateo, CA: Morgan Kaufmann.
Luger, G. F. (2002). *Artificial intelligence: Structures and strategies for complex problem-solving.* Reading, MA: Addison Wesley.
McNamara, D. S., de Vega, M., & O'Reilly, T. (in press). Comprehension skill, inference making, and the role of knowledge. In F. Schmalhofer & C.A. Perfetti (Eds.), *Higher level language processes in the brain: Inference and comprehension processe*s. Mahwah, NJ: Erlbaum.
Nicoll, HG., Francisco, J., & Nakhleh, M. (2001). A three-tier system for assessing concept map links: A methodological study. *International Journal of Science Education*, 23, 863-865.
Novak, J. D., & Canas, A. J. (2006) *The theory underlying concept maps and how to construct them*. Florida Institute for Human and Machine Cognition, University of West Florida.
Novak, J. D. & Gowin, D. B. (1984). *Learning how to learn.* UK: Cambridge University Press.
Sen, A. I. (2002). Concept maps as a research and evaluation tool to assess conceptual change in quantum physics. *Science Education International,* 13, 14-24.
Sowa, J. F. (2000). *Knowledge representation: Logical, philosophical, and computational foundations.* NY: Brooks Cole
Romance, N. R., & Vitale, M. R. (2001). Implementing an in-depth expanded science model in elementary schools: Multi-year findings, research issues, and policy implications. *International Journal of Science Education, 23,* 373-404.
Romance, N. R., & Vitale, M. R. (1999). Broadening the framework for student-centered instruction: Using concept mapping as a tool for knowledge-based learning. *College Teachin*g, 47, 74-79.
Romance, N. R., & Vitale, M. R. (1997). *Constituents of instructional environments for enhancing conceptual understanding in science.* Paper presented at the Fourth International Seminar: From Misconceptions to Constructed Understanding. Cornell University, Ithica, NY.
Romance, N. R., Vitale, M. R., & Dolan, M. F. (2004). *Scientifically-based research in science education.* US Department of Education Monograph Series, Washington, DC: US Department of Education.
Romance, N. R., Vitale, M. R., & Haky, J. (2000). Concept mapping as a knowledge-based strategy for enhancing student understanding. *The NSF Workshop Project Newsletter*, *2*, 5-8.
Schmidt, W. H., McKnight, C. C., Houang, R. T., Wang, H. C., Wiley, D. E., Cogan, L. S., et al. (2001). *Why schools matter: A cross-national comparison of curriculum and learning*. San Francisco: Jossey-Bass.
Vitale, M. R., & Romance, N. R. (2006) Research in science education: An interdisciplinary perspective. In J. Rhoton and P. Shane (Eds.). *Teaching science in the 21st century.* Arlington, VA: NSTA Press.
Vitale, M. R., & Romance, N. R. (2000). Portfolios in science assessment: A knowledge-based model for classroom practice. In J. J. Mintzes, J. H. Wandersee, & J.D. Novak (Eds.), *Assessing science understanding: A human constructivist view.*(pp. 168-197). San Diego, CA: Academic Press.
Vitale, M. R., Romance, N. R., & Dolan, M. F. (2006). A knowledge-based framework for the classroom assessment of student science understanding. In M. McMahon, P. et al (Eds.). *Assessment in Science: Practical experiences and educational research.* (pp. 1-14). Arlington, VA: NSTA Press.

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CONCEPT MAPS AS A STRATEGY TO ASSESS LEARNING IN BIOCHEMISTRY USING VIRTUAL DYNAMIC METABOLIC DIAGRAMS (DMDV)

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Abstract . This study reports the application of concept maps to follow the Krebs cycle and carbohydrates metabolism apprenticeship using educational software called Virtual Dynamic Metabolic Diagram (Diagrama Metabólico Dinâmico Virtual, or DMDV). Two experiments were performed with undergraduate students of the medicine course while the software was being developed. The first composed by 24 students used DMDV preliminary version of the software containing Krebs Cycle, and the second composed by 36 students used the new version the DMDV program, containing contents of additional metabolic pathways. All students could access the system at anytime through an intranet. Concept maps were used in this study assessing learning and identifying misunderstood concepts by the students after the used DMDV. Concept maps permit the representation of new knowledge in the course of study, perceived as the processes of assimilation and adaptation of new mental schemes, in terms of reflective abstraction (Piaget, 1995). The evaluation was made by analyzing three concept maps made by each student at a different time: (a) one map before initiating the study with DMDV; (b) the second just after the study; and (c) the third two months later. Criteria for the analysis were: predominance of associative over classificatory character; correct concepts and relationships; coherence; number of relationships; creativity and logic. The initial maps showed that all students had some previous mental scheme about the proposed concept. All final concept maps showed an expansion of the concepts as compared to the initial maps, something which can be seen even by a mere glance at the size of the maps. A purely visual comparison between the maps indicated that new elements had been added. The associative character has been shown to predominate over the classificatory one. The results obtained suggest the validity of using concept maps as a strategy to monitor the cognitive process, both by the teacher and by the student him/herself and apprenticeship using educational software DMDV

1 Introduction

This study reports the application of concept maps to follow the Krebs cycle and carbohydrates metabolism apprenticeship using an educational software called Virtual Dynamic Metabolic Diagram (Diagrama Metabólico Dinâmico Virtual, or DMDV). The learning subjects were undergraduate students of the medicine course of the Federal Foundation School of Medical Sciences of Porto Alegre (FFFCMPA), Brazil.

Concept maps, founded in meaningful learning according to Ausubel theory and the Novak (1998) proposals are used as tools to organize and present knowledge. They are an important teaching and learning support for use by teachers and students. Concept maps are graphical representations of related concept systems in any domain, disposed to show the relationships among them and the whole system, allowing the perception of each connection (Moreira & Buchweitz, 1987).

The process of producing a concept map affords the development of a cognitive learning process in which the student organizes his/her knowledge autonomously, identifying in an oriented way the acquisition of new pieces of information, which will be integrated into his/her previous knowledge. As a learning tool, it can be used by the student to, e.g., making notes, solving problems, planning the study and/or writing of long reports, preparing for examinations, and identifing the connection of topics.

For the teachers, concept maps can help:

- making difficult concepts clear, organized in a systematic order;
- keeping focus on key concepts and their interconnections;
- conveying a clear general picture of the topics and their relationships to the students;
- offering a reflection support of the student about their own representation;
- allowing the visualization of key concepts and summarizing their interconnections;
- assessing learning and identifying misunderstood concepts by the students;

- evaluating the teaching process;
- evaluating the attainment of goals by the students through the identification of misunderstood and missing concepts.

An example of the use of concept maps in Biochemistry can be found in Campbell (2000). At the beginning of each chapter, the author presents a concept map of the topics that will be dealt with therein, characterizing an important reading support tool. Another example in Biochemistry it is in a book by Richard Harvey and Pamela Champe (2005). Since students often view Biochemistry as a pile of facts or equations to be memorized rather than as concepts to be understood, these authors created a series of concept maps about the biochemical contents to illustrate graphically the relationships between the ideas presented in a given chapter, as well as to show how information can be grouped or organized. For these authors a concept map can be used as a tool by a student him/herself to visualize the connections between the concepts. Differently from the educators who define concepts as perceived consistencies in events or objects, these authors understand concepts in biochemical concept maps as abstractions (e.g. free energy), processes (e.g. oxidative phosphorylation), and compounds (e.g. glucose-6-phosphate).

According to Jean Piaget the development of the human cognitive process, the building of concepts is a system in which their elements are necessarily supported on one another, while at the same time being open to multiple exchanges with the outside. It is thus assumed that it is impossible to build a single concept A as a starting point in a classification without using other domain-related concepts, which characterizes a non-hierarchical, dynamic process of interconnected variables. According to Dutra, Fagundes and Cañas (2004)[1]: "(...) in the dynamic of making a concept map one can follow the representation of a system of meanings activated in an individual so that in it we also recognize subsystems that relate to one another by mutual support in the building of such meanings".

In the present work, concept maps have been used as tools to represent knowledge, from an instrumental point of view, i.e., as a tool to support students' and even teachers' expression. From the conceptual point of view, they were used according to the Piagetian view of concepts formation, described by Dutra, Fagundes and Cañas (2004). This means that these instruments have been given the ability to represent systems of preexisting meanings in students, as well as activation of later constructions, and possible subsystems of signification associated with the concepts of the content at issue. By the analysis of concepts and linking sentences made by the student, we aimed to ascertain (1) the student's knowledge of the studied topic, (2) the influence of the use of the educational software, and (3) how the student would represent his knowledge two months after completion of the study.

Concept maps focus on aspects relating to the conceptual structure of content, and therefore they were considered as instrumental for evaluation purposes, so as to add conceptual and pedagogical value to the traditional forms of evaluation, i.e. through tests. This stance is supported by various authors who have done research on concepts maps as a support of teaching activities. According to Farias (1995, p. 23), "(...) for a student to elaborate a correct concept map, he/she must have a wide understanding of the studied material, differentiating between more general concepts and the various levels of subordinate concepts". This view had been previously presented by Stewart, Van Kirk and Rowel (1979 apud Farias, 1995), who think that concept maps appear to evaluate student's knowledge more effectively than other evaluation tools, because they depict the structure of the studied content.

In order to facilitate the student's understanding of the metabolic pathways and provide greater interaction with the contents and thus better learning an software, called Virtual Dynamic Metabolic Diagram, was developed which allows the user to learn, study, and review contents concerning Krebs Cycle and carbohydrate metabolism through:

a. interactive games with a string of substrates and enzymes of the metabolic pathways, their control, inhibition, role of vitamins in their correct functioning, and their connection with other systems;

b. readings on the functions and characteristics of metabolic pathways, as well as historical milestones along their development;

c. solving of essay and multiple-choice questions.

[1] Electronic document, referenced at the end of this paper.

2 Methods

After the pilot trials in using the preliminary version of the software containing Krebs Cycle, reported in Azevedo, (2003; 2003a and 2004), a second trial with a new version of the software containing contents of other metabolic pathways. The software was evaluated by two groups of undergraduate students regularly enrolled in the discipline of biochemistry. All students could use the software for studing during two classes in a computer room. In the following week, before the evaluation of the discipline concerning this topic, the software was made available again through the intranet of the institution. All students were registered on the system, and their access, through use of a personal password, allowed the recording of activities on an individual basis.

Two groups of students were tested on the application of concept maps as a tool to assess learning after the use of the DMDV software educational for the Krebs cycle and carbohydrates metabolism. While the first group used concept maps to depict their knowledge of the Krebs Cycle, the second group worked with a wider content, including the Krebs Cycle as well as Carbohydrates Metabolism. The content didn't work in the expositive class, only in the software that make possible a comprehensive student interaction, making possible the initiative and autonomy of the student during the activity. The software makes possible the student action with the logic sequence game, to do the metabolic route, and with the classmates, to access new information through the hypertexts, available in the virtual environment or in the internet, or still to consult texts or printed books. This experience was realized with the target that the students did a activity of concept' contrution and no to repeat the expositives class informations. The construction of a concept map permits the representation of knowledge during the study, perceived as the processes of assimilation and adaptation of new mental schemes, in terms of reflective abstraction (Piaget, 1995). The evaluation was made by analyzing three conceptual maps made by each student: (a) one map before initiating the study with the DMDV; (b) the second just after the study and; (c) the third two months later. This analysis used the following criteria: predominance of associative over classificatory character; correct concepts and relationships; coherence; number of relationships; creativity and logic.

3 Analysis of Concept Maps

Some general observations about the concept maps of all participants can be made from an analysis of the whole. The initial maps indicate that all students had some previous knowledge of the proposed concept. All final concept maps showed an expansion of the concepts as compared to the initial maps, something which can be seen even by a mere glance at the size of the maps. A purely visual comparison between the maps indicated that new elements had been added. Some initial maps presented few concepts and relations. A purely visual comparison between the maps indicated that new elements had been added, reinforcing the opportunity of using concept maps in the learning process.

Students with less previous knowledge (fewer representations in the initial map) presented more expansion on the final map (showing changes that occurred in the students' previous ability to represent).

With rare exceptions, both the initial and the final map of all participants were coherent, cohesive, expressive and logic.

The maps also showed another characteristic that is desirable for the teaching-learning process: the interrelation of concepts, so that they are not characterized as fragments but as parts of a whole, whose interconnections are crucial for understanding the content in its more complex sense, which includes generalizations, abstractions and content disposition by order of relevance and meaning. For example, on the third concept map, the concepts of relations with the synthesis of urea, function of the cycle, and control were more associated, which gives a perfect idea of the insertion of the concept in a contextual whole show examples of these relations in the maps of two students). On the second map, in addition to function, location and characteristics, there appeared the list of names of substrates, concepts that are related to structured memory. An analysis of the relations between the concepts depicted on students' concept maps shows that these concepts were better understood. Interestingly, the first maps often presented the word "is" to indicate a relation, while the two later maps indicated relations using words like "oxidizes", "yields", and "synthesizes", etc..

All maps included concepts related to function, location and characteristics of the metabolic cycle. The second map also showed the names of the substrates and enzymes of the cycles, which seems to suggest enhancement of memorization soon after using the computer program.

Besides representing the student's previous and learned knowledge, supporting the applicability of the tool as a strategy to monitor the cognitive process by the teacher, concept maps also became an important tool for student self-evaluation. Oral evaluations made by the students were determinant for this observation. Some students reported that the first map was difficult to draw and after the game, it was easy to draw the second. Such stance refers to students' awareness of their the learning process, whose indicator is the map itself.

Due to the limitation ot pages in this article, we selected randomly concept maps from one stundent of each group to illustrate our analysis.

Figures one to six show examples of the first, second and third concept maps drawn by the same student, in the two tested groups, whose result of map analysis was similar.

3.1 First examples of Concept Maps by the same student

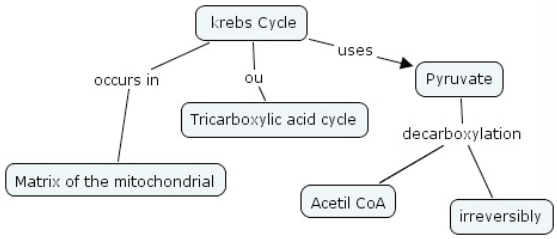


Figure 1. First Map presents some previous knowledge

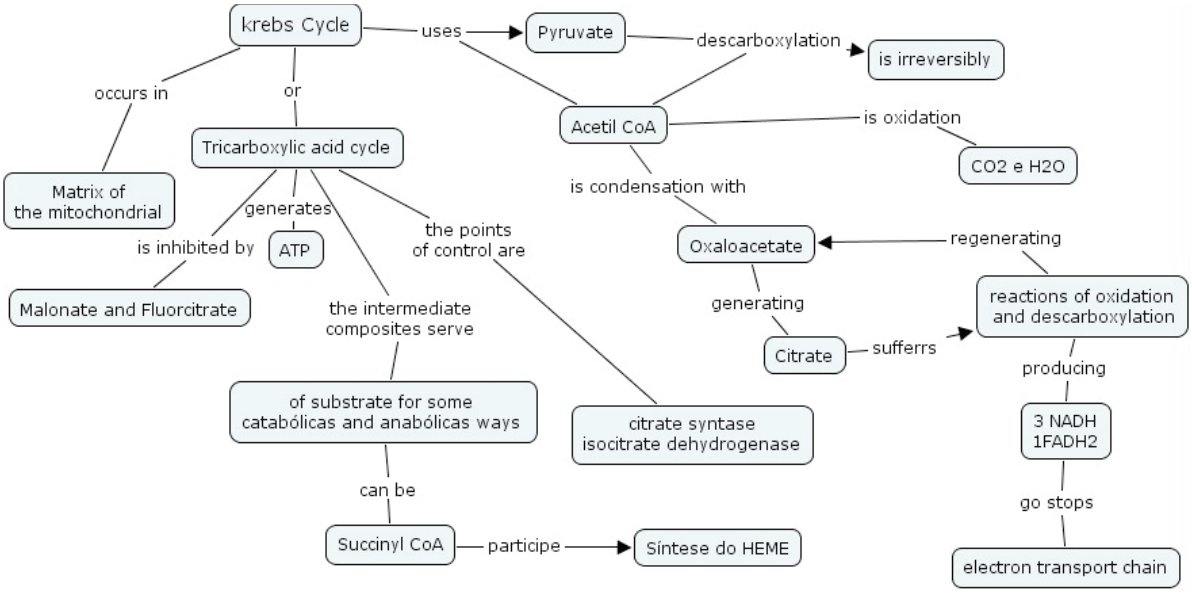


Figure 2. Second map presents expanded knowledge

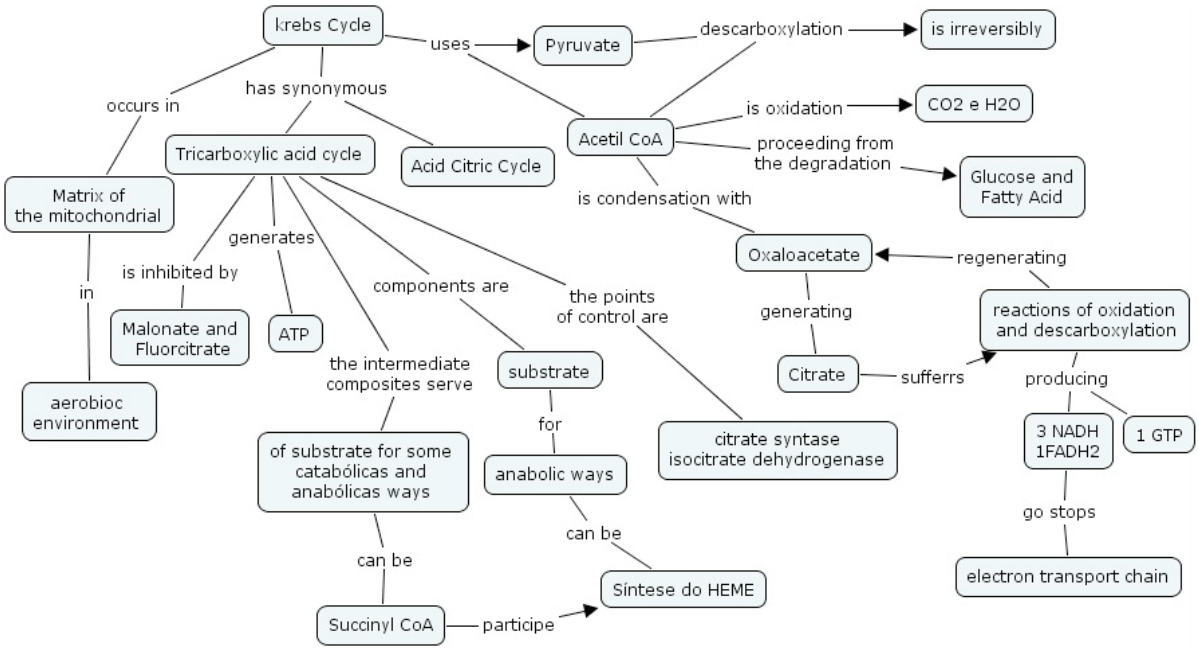


Figure 3. Third map presents more general concepts and interrelations with other metabolic routes

3.2 Second examples of Concept Maps by the same student

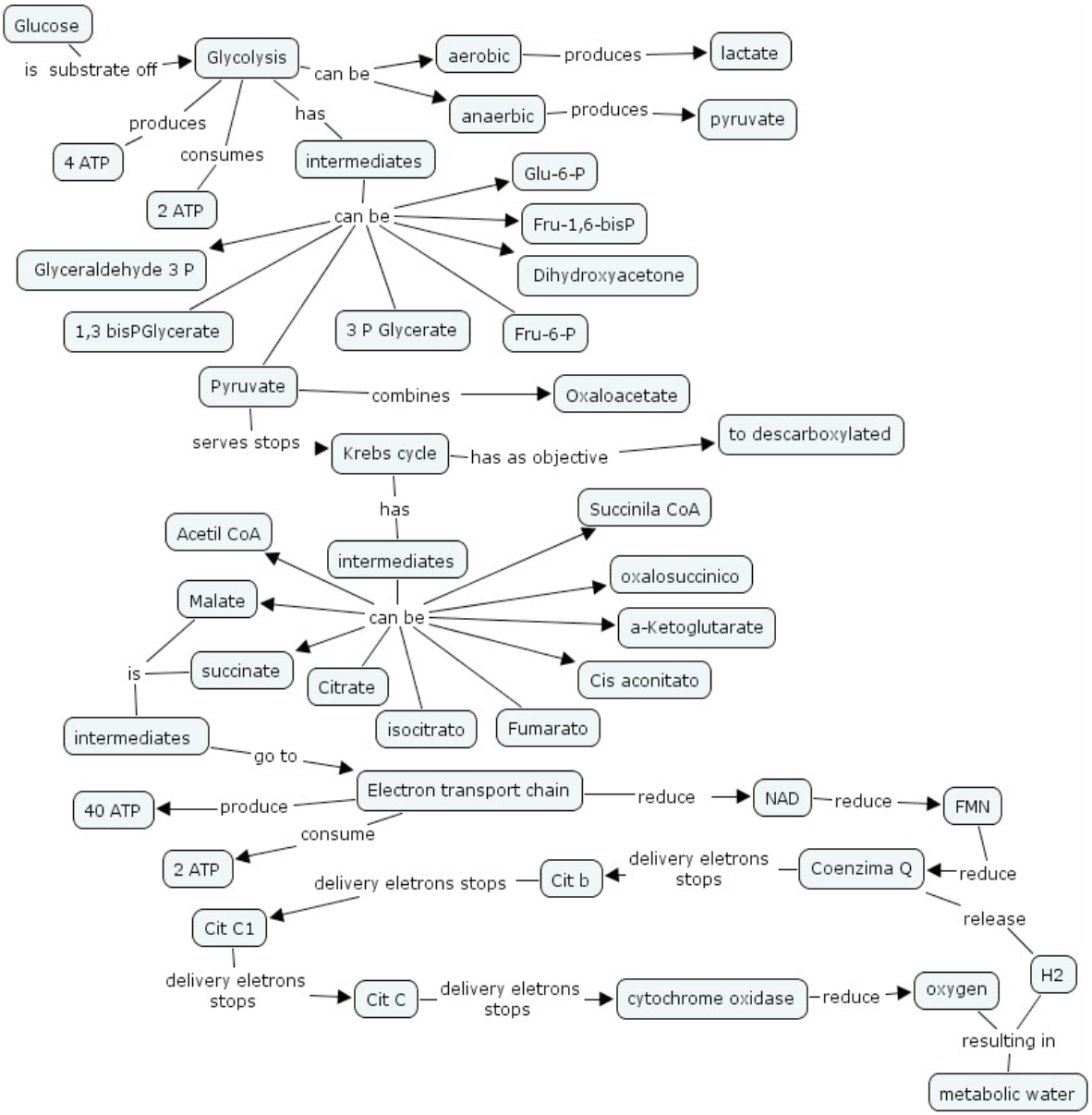


Figure 4. First Map presents much previous knowledge

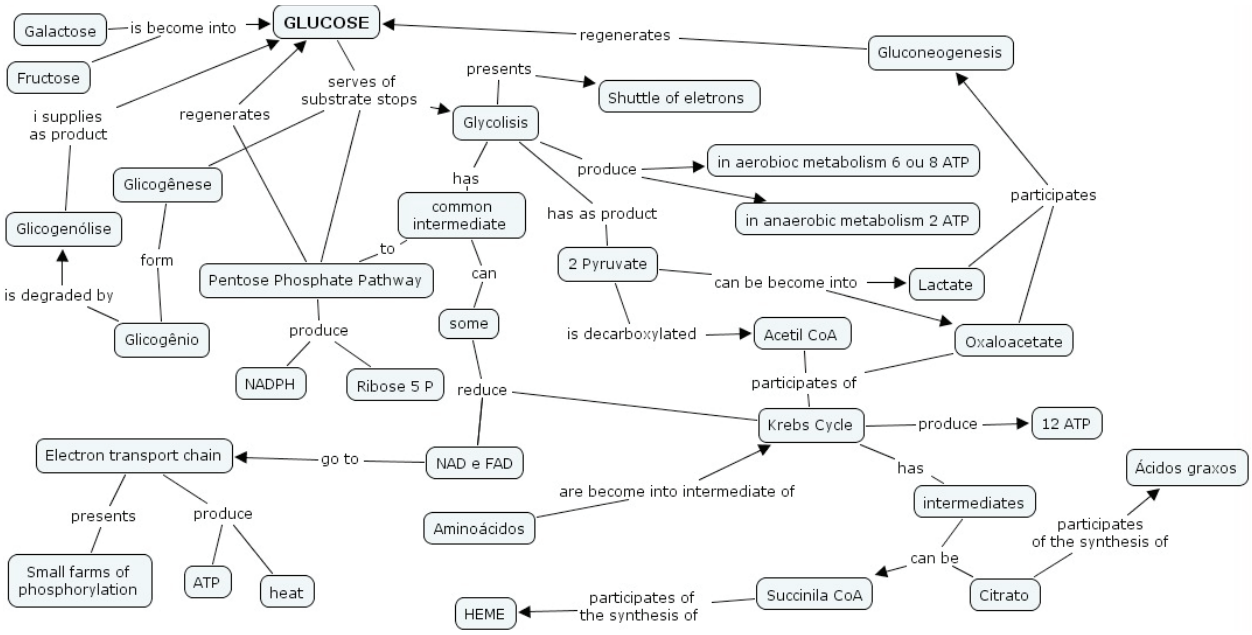


Figure 5. Second Map concept map drawn after the game presents progress concerning the interrelation of concepts

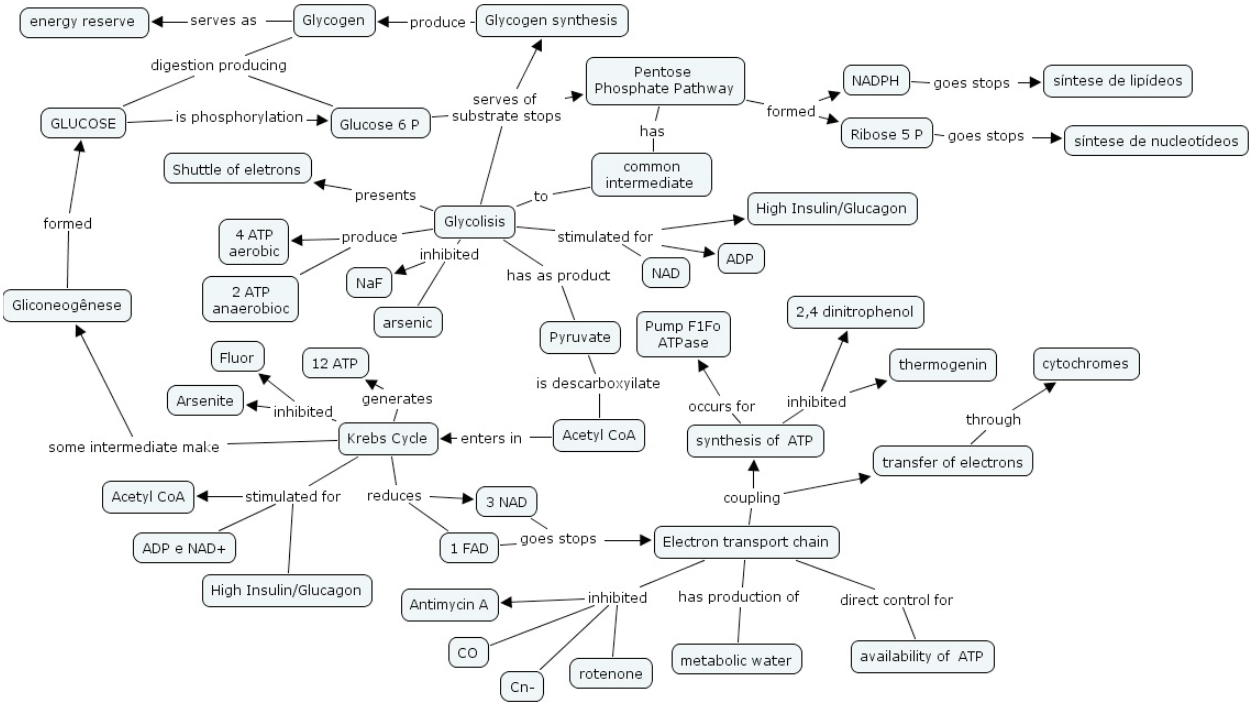


Figure 6. Third map maintained the expanded knowledge, presented more general concepts organized in a coherent way and associated with the studied content.

4 Conclusions

More than reporting the use of concept maps with medical students of the FFFCMPA, this work intended to call the attention of professors and researchers in the field of Biochemistry to the potentiality of this teaching/learning resource, in terms of content organization, self-learning and follow-up of the activities of each student, from the perspective of increasing their knowledge of the subject. The concepts maps construction activity provoked a permanent quest activity of new information and offering feedback making possible asked about representations constructs in the conceptl maps. We thus have briefly presented this potentiality and, through the case presented – which originated the author's doctoral dissertation in the Postgraduate Program of Computer Science in Education of the Universidade Federal do Rio Grande do Sul – we have tried to illustrate the outcomes of its utilization. Although in one of the experiments a more comprehensive concept was requested (Carbohydrates metabolism) in addition to the Krebs cycle, the analysis of the three concept maps drawn by the students in both experiments showed similar results.

The efficiency of the tool could be ascertained by comparing the three concept maps of each student, which allowed the teacher to follow up the building of knowledge by the student, according to the idea of conceptual development, proposed by Piaget, of concept formation from previous mental structures in the learner (Piaget, 1978). The initial maps showed that all students had some previous knowledge of the proposed concept; there was an aggregation of new elements on all later maps of all students. Both the students with less previous knowledge (fewer representations in the initial map) and those with greater previous knowledge presented expansion on the final concept map as well as progress concerning the interrelation of concepts, indicating a more complex level of conceptualization. Differences can be seen between the relations between the concepts placed on the three maps, suggesting that there was a deeper understanding of these relations and of the sense of the concepts. In the dissertation, these results were associated with other evaluation tools (tests), indicating that concept maps can be characterized as effective tools to follow up the process of conceptual development in each student. Future research point to the advantages of their systematic use in educational activities in such areas as Biochemistry.

5 References

Azevedo, A. M. P.; Lazzarotto, G.; Falkembach, G. A. M.; Zaro, M. A.. *Ambientes virtuais de ensino para a Bioquímica: jogo e multimídia como apoio à aprendizagem* In: XIV SBIE - Simpósio Brasileiro de Informática na Educação, 2003, Rio de Janeiro. Anais do XIV SBIE. Rio de Janeiro: Sociedade Brasileira de Computação, 2003. v.1. p.728 – 737

Azevedo, A. M. P., Lazzarotto, G. B., El *Software Diagrama Metabólico Dinâmico Virtual*, In: Taller Internacional de Software Educativo, Memorias..., Santiago, Chile. 2003a.

Azevedo, A. M. P., Lazzarotto, G. B., Timm, M.I.; Zaro, M.A. Relato de uma experiência com o uso do Diagrama Metabólico Dinâmico Virtual do Ciclo de Krebs. RENOTE - Revista Novas Tecnologias na Educação, ISSN 1679-1916, Vol. 2 No 1, Porto Alegre. 2004.

Champe, P. C.; Harvey, R.A.; Ferrier, D.R. *Lippincott's illustrated reviews:* biochemistry. 3 th. Philadelphia: Lippincott Williams e Willians, 2005.534p.

Dutra, I.M.; Fagundes, L.C.; Cañas, A.J. *Uma proposta de uso dos mapas conceituais para um paradigma construtivista da formação de professores à distância*. In: WORKSHOP SOBRE INFORMÁTICA NA ESCOLA, 10, 2004, Salvador. Disponível em: <http://www.emack.com.br/info/ apostilas/ nestormapas_piaget.pdf>. Acesso em: 20 jul. 2005.

Faria, W. Mapas conceituais**:** aplicações ao ensino, currículo e avaliação. São Paulo: EPU, 1995. (Temas básicos de educação e ensino).

Novak, J. D. *Learning, Creating, and Using Knowledge: Concept Maps(R) as Facilitative Tools in Schools and Corporations.* Mahweh, NJ, Lawrence Erlbaum Associates, 1998.

Moreira, M.A.& Buchweitz. B. *Mapas conceituais***:** instrumentos didáticos de avaliação e análise de currículo. São Paulo: Editora Moraes, 1987, 83 p.

Piaget, J. *O nascimento da inteligência na criança*. 3. ed. Rio de Janeiro: Zahar, 1978. 389 p.

Piaget, J. **Abstração reflexionante:** relações lógico-aritméticas e ordem das relações espaciais. Porto Alegre: Artes Médicas, 1995. 292 p.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

CONCEPT MAPS USED AS A "KNOWLEDGE AND INFORMATION AWARENESS" TOOL FOR SUPPORTING COLLABORATIVE PROBLEM SOLVING IN DISTRIBUTED GROUPS

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Abstract. In today's information society, computer-supported collaborative learning (CSCL) has become increasingly important. However, there are still problems regarding CSCL, especially interaction problems within groups. This study is an investigation of whether a specific kind of awareness tool, namely a tool for making the collaborators aware of relevant domain knowledge and the information underlying this knowledge, is an efficient means to foster computer-supported collaborative problem solving in the context of resource-based learning. In the study presented, an experimental condition, in which the group members of a triad had a "knowledge and information awareness" tool (KIA-Tool), is compared to a control condition, in which the group members did not have it. First results showed that, despite additional information the participants in the experimental condition had to deal with, the KIA-Tool leads to higher performance.

1 Introduction

In today's information society, Network-based collaborative problem solving by spatially distributed group members is becoming increasingly important. However, problems in collaboration arise because of a variety of factors, among them the lack of competency in structuring collaboration in shared virtual work spaces, the lack of awareness regarding the availability and activities of the group members, and a lack of awareness about their knowledge of subject matter and their mental representation of a particular problem situation. Because of the complexity of influencing factors in Web-based scenarios, individuals often suffer from cognitive overload as well as from conceptual and navigational disorientation (Bleakley & Carrigan, 1994). In order to collaborate effectively, group members often need to organize and represent subject-matter knowledge as well as task-relevant information resources associated with it. Research in computer-supported collaborative learning (CSCL) has yielded valuable knowledge regarding how to foster this style of learning. Two strands of research address problems relative to CSCL. On the one hand, there are approaches that support CSCL by explicit methods like scripting (e.g., Kollar, Fischer, & Slotta, 2005). On the other hand, there are approaches that seek to support CSCL by using implicit methods focused on enhancing different kinds of group awareness (e.g., Gross, Stary, & Totter, 2005). Awareness according to Endsley (1995) is concerned with "knowing what's going on" in a group situation. Until now, research on fostering awareness has focused on social and behavioral aspects, i.e., knowledge about current availability and activities of the group members (e.g., Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003). However, the authors of this paper suggest that social and activity awareness may not be enough to support effective collaboration. Knowledge is needed about the mental representations regarding the task domain of each of the group members, the concepts and information resources they use and share, as well as the knowledge gaps that are responsible for misunderstandings, ineffective shared knowledge construction, and deficient problem solving.

Graphical external representations are suggested to foster externalized cognition (e.g., Cox, 1999) and enhance the cognitive processes of managing knowledge and information in resource-based learning and problem solving environments. Knowledge and information visualizations have been shown to be effective for enhancing the cognitive processes of retrieving knowledge and task-relevant information (Tergan & Keller, 2005). Particularly, digital concept maps seem to have a potential as cognitive tools that may enhance individual and group-related cognitive processes in resource-based learning and problem solving (Tergan, 2005; Tergan, Keller, & Burkhard, in press). This paper ties in with the research endeavors of fostering knowledge and information awareness as a means for making the collaboration of spatially distributed group members more effective. A "knowledge and information awareness" tool (KIA-Tool) has been invented to make the knowledge of the collaborators about the concepts that have been used and the available information resources visible, and to support shared knowledge construction and collaborative

problem solving. An empirical study investigating the potential of the KIA-Tool for supporting CSCL and its results are presented and discussed. The paper ends with a conclusion.

2 Problems of Computer-Supported Collaborative Learning

Computer supported collaborative learning and meaning making becomes increasingly important when learners have to construct a shared knowledge basis in order to cooperatively solve problems by using the Internet as a communication medium. According to Koschmann (2002) CSCL could be characterized as "practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts" (p. 18). Following this often cited definition, there are two important features that characterize CSCL: First, the collaboration aspect implies that a group, not only an individual, is involved. Stahl, Koschmann, and Suthers (2006) explain that this group learning "is not merely accomplished interactionally, but is actually constituted of the interactions between participants". This statement points out that in such situations the interaction between the group members is essential for group efficiency. Second, Koschmann's definition highlights the aspect of mediation through designed artifacts. This aspect refers to the computer support of the group interaction, i.e., the technology should be designed to mediate and encourage social acts that lead to efficient group work.

Results of empirical research suggest that learners in CSCL scenarios may provide more complete reports, may make decisions with higher quality, and may be better in idea generation (Fjermestad, 2004). However, research results also show that efficient computer-supported collaboration is not easy to achieve (Dewiyanti, Brand-Gruwel, & Jochems, 2005; Salomon, 1992). According to Janssen, Erkens, Jaspers, and Broeken (2005) groups who are learning collaboratively with computer support often have communication and interaction problems. They may perceive their discussion as confused (Thompson & Coovert, 2003), they may need more time to arrive at a consensus and for making decisions (Fjermestad, 2004), and they may need more time for solving tasks (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002). Following, for example, Carroll et al. (2003), in CSCL the group task is often not perceived as a group task; i.e., the group members work individually instead of collaboratively and coordination is missing. In addition, the individual group members often do not trust in the fact that the others are doing their part of the work. Additionally, the group members often do not perceive changes in the situation, the task, or the group.

CSCL research aims at studying the process of collaboration as well as the effectiveness of measures and tools for fostering collaboration and cooperation in computer-based learning and problem solving scenarios. The focus of empirical research in this area is generally on the study of methods and tools for scripting the communication process. Other research endeavors focus on methods and tools for fostering coherence and effectiveness of group processing by enhancing awareness with respect to group processes. As outlined in the introductory section, processes and effectiveness of cognitive awareness of the individual and the shared knowledge of the group members, as well as the information resources that are required for learning and problem solving, have not yet been studied.

3 Knowledge and Information Awareness to Enhance Computer-Supported Collaborative Learning

In the literature, there is no consensus about how the term awareness is described and defined. Following Christiansen and Maglaughlin (2003), there are 41 types of awareness. However, other authors try to differentiate awareness according to several dimensions. Carroll et al. (2003) for example, differentiate different types of awareness on the working processes level. While social awareness is defined as awareness regarding who is currently available for collaboration, action awareness additionally provides information regarding who is doing what at the moment as well as what happens currently. This last type of awareness refers to feedback on single occurrences. However, Carroll et al. (2003) point out the importance of activity awareness for computer-supported collaborative scenarios. They defined activity awareness as awareness regarding not only the information on who is currently available and who is doing what at the moment, but also awareness regarding the relevance of an activity with regard to the goal of the group.

However up to now, Carroll and his colleagues have not conducted controlled empirical studies to provide evidence for the efficiency of activity awareness.

In most papers, the meaning of awareness refers to both social awareness, in the sense of who belongs to the group and who is available, and action awareness, in the sense of who is doing or who did what. In collaborative problem solving when group members construct different individual knowledge representations based on different information resources and lack knowledge because of lacking information, social and activity awareness must be supplemented with "knowledge and information awareness". A KIA-Tool might be used to enhance computer-supported collaborative learning by visualizing individual and shared knowledge as well as other related information. Such a tool might make individual group members aware of the knowledge of the other group members regarding the task domain as well as the information underlying that knowledge. Visualizations should externalize the knowledge structures and display the related information of the collaboration partners to support external cognition about the status of shared knowledge construction and the processes of knowledge communication.

Concept maps, developed by Joseph D. Novak (e.g., Novak & Gowin, 1984), are a type of knowledge visualization for representing the knowledge of a learner by means of nodes displaying concepts and labeled links between the nodes representing the relations between the concepts. While traditional concept maps were created by using paper and pencil, computer-based concept mapping tools allow for the creation of digital concept maps. An example is CmapTools developed by the Florida Institute of Human Machine and Cognition in Pensacola, FL (USA) (see, http://cmap.ihmc.us/). Traditional concept maps have been criticized for some shortcomings in representing knowledge. For example, they only visualize abstract concept knowledge leaving the content knowledge behind the concepts (e.g., examples and images) unconsidered (e.g., Tergan et al., in press). By contrast, advanced digital concept mapping tools allow the representation of content knowledge as well as hyper-linking a concept with additional information regarding the concept. When using a KIA-Tool users are not only able to check visually which concept is based on an information resource, but also can access information relevant for an explanation of a concept and its relation to other concepts. It is suggested that being aware of one's own knowledge and the knowledge of others as well as the information resources linked to a concept may help cooperative learners and problem solvers in shared knowledge-construction and problem-solving tasks. CmapTools as a digital concept mapping tool provides facilities suited to the use of digital concept maps as KIA-Tools.

It is assumed that a KIA-Tool is helpful in a computer-supported collaborative learning scenario, because it could be expected that such a tool would have a positive impact on interaction, especially on the processes and the effectiveness of communication, coordination, and collaborative problem solving. On the one hand, following Clark and Brennan (1993) shared understanding in communication is crucial for learners working in groups. Making visual representations of the knowledge structures and the underlying information of each group member available to the group should facilitate shared understanding and knowledge construction. By referencing to the external representations, the group members are made aware of the status of individual knowledge representations. On the other hand, exchange of unshared information is very important (e.g., Stasser, Vaughan, & Stewart, 2000). It is shown that in CSCL information that is shared by all members is often mentioned in group discussion, while unshared information that is known by only one group member is often not mentioned. By comparing the external representations of the knowledge structures of the collaborators, group members can easily recognize which information is shared and which is not. This should have a positive effect on group coordination. In addition, it is assumed that the capability to view the knowledge of the others in the group provides a kind of affordance to make use of these representations (Suthers, 2005). The study outlined in the following passage tested these assumptions.

4 Experiment

This experiment investigated whether a tool for supporting awareness regarding the knowledge and information of the collaborators (KIA-Tool) leads to more efficient collaboration (in the sense of coordination and communication) of a group, and as a result, to more efficient problem solving compared to a condition with groups that did not use a KIA-Tool.

4.1 Method

4.1.1 Participants

Participants were 90 students (58 female, 32 male) of the University of Tuebingen, Germany. Average age was 24.47 (SD = 3.83). The students were randomly assigned to the experimental condition or to the control condition. Each group consisted of three participants, resulting in 15 control groups and 15 experimental groups.

4.1.2 Materials and Procedure

The participants worked in groups of three students in a room that was divided by partition walls into three separate sections. Each of the sections was equipped with a desk and a computer. The participants could not see each other, but could speak with each other. They were required to work in a spatially distributed, synchronous fashion with net-based, shared and unshared tools. The experimental environment used in this study provided information elements that are necessary to care for a fictitious kind of spruce forest. These information elements consisted of 13 concepts, 30 relations between these concepts, and 13 background resources (in parts divisible in sub-elements) and were evenly distributed among the three group members. Each participant had several unshared items, several items that were shared with one group member, and others that were shared with both group members.

The experimental environment consisted of two different software components. The first was an information space that contained the different information units the group members needed for solving the problems. This information space was based on Bebop, a Zope3-based groupware that was developed by Oestermeier, Kurbad, Knobloch, and Armbruster of the Institute of Knowledge Media in Tuebingen (Germany) (see, http://svn.iwm-kmrc.de/). The other was CmapTools (see section 3).

At the start of the study, the participants took a pencil-paper diagnostic test to measure several control variables including their experience with computers, mapping techniques, and group working skills. Afterwards, they received an introduction and practice using CmapTools. After ensuring that all participants could use CmapTools without problems, they started with individual phase 1 of the experiment. At the outset of this phase, participants were told that they are experts who have to protect a spruce forest and that they first have to refresh their domain expertise, before they start to collaborate and to find a common solution for the problems. During this phase, which lasted 23 minutes, the group members worked separately, accessing the information elements in their Bebop window and structuring their information and knowledge in their own working window (see Figure 1).

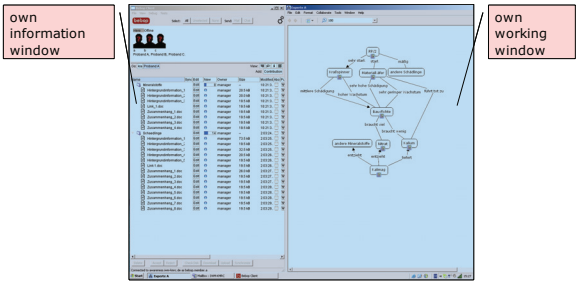


Figure 1. Individual phase 1.

In the individual phase 2, each participant of the control group had 5 minutes to examine his/her own map (see Figure 2, left side). Each participant of the experimental group, however, had 5 minutes to view his/her own map as well as the maps of his/her collaborators (see Figure 2, right side). After this activity, all participants had to fill out a questionnaire used as a manipulation check. This questionnaire contained 15 multiple choice items that measured the amount of knowledge the participants acquired from the maps.

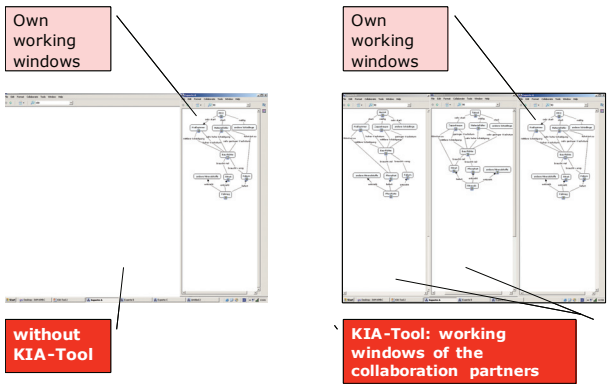


Figure 2. Individual phase 2 (left: control group; right: experimental group).

Subsequently, the three group members had to collaborate to solve two problems, i.e., which pesticide and which fertilizer they would use to protect and to cultivate the spruce forest. To solve these problems the participants needed to compile the knowledge and information they had structured and visualized in the individual phase 1 in the form of a digital concept map. To do this, they used a shared working window to create a common digital concept map containing all the knowledge and information they acquired in the individual phase. They had 40 minutes for collaboration. While collaborating they could speak with each other. They were told that they were using a kind of hands-free speaking system. In the control condition, the participants could only see their own working window and the shared working window (see Figure 3, left side). In the experimental condition, the participants also saw the individual maps of their collaborators, i.e., they were also aware of the knowledge and information their collaborators had (see Figure 3, right side). The individuals' interactions through the software and the audio data were recorded.

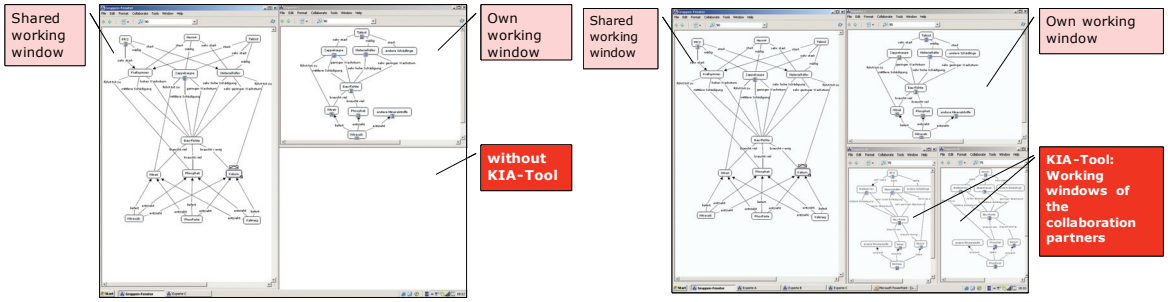


Figure 3. Individual phase 2 (left: control group; right: experimental group).

After this collaborative phase, the participants received another test containing 30 items to measure the knowledge they acquired regarding taking care of the spruce forest. In this test phase, the experimental environment was no longer available. There were no time limits on this test. At the end of the study, participants had to fill out a questionnaire asking for difficulties regarding communication and collaboration, the use of CmapTools, and how helpful the KIA-Tool was.

4.1.3 Design and Dependent Measures

The experimental analysis was based on a comparison of the control condition and the experimental conditions. In the experimental conditions, the participants were provided with a KIA-Tool, that is, they could see the individual concept maps of their collaboration partners and therefore were aware of the knowledge and information their collaborators had. In the control condition, the participants could not use a KIA-Tool.

With regard to the dependent measures, the distinction was made between product-related measures and process-related measures. The product-related measures could be divided into three types:

- First, the domain knowledge measured with 30 multiple-choice test items: Several sub-variables could be differentiated, for example, knowledge regarding relations and contents underlying a concept as well as knowledge pertaining to whether it is unshared, shared with one other member, or shared with both members.
- Second, the quality of the common concept map that the group created in the collaboration phase: Several description variables are differentiated, for example the number of correct nodes and relations, and the number of annotations.
- Third, the quality of the group answers to the two problem-solving tasks.

Regarding the process-related measures, the communication and collaboration aspects were of interest. In the collaboration phase, the development of the group map was recorded in a log file and the verbal communications were recorded in an audio file for later analysis. In addition, some subjective items in a questionnaire were captured. Although data analysis is still in progress, initial results are reported in the next section.

4.2 Results and Discussion

In all analyses of variance reported in this paper, the control measure item "experience on creating computer-based graphics" was used as a covariate. The reason is that with regard to this item, a significant difference existed between the control condition and the experimental condition, with a higher value in the sense of more experience in the control condition. Additionally, this item is strongly associated with dependent measures. With regard to other control items, there were no significant differences between the control and the experimental condition. All analyses presented here are based on group level, that is, the group values are calculated as means of the values of the individuals of a group. Analysis on the group level was necessary, due to the fact that the individuals in a group were not independent of each other.

The first analysis determined whether the KIA-Tool was used by the participants. For this purpose, some questionnaire items were analyzed that consisted of five-point rating scales with the number one for "no agreement", the number three for "partial agreement" and the number five for "complete agreement": The experimental groups agreed on average that it was helpful to have an overview of the maps of the collaborators (M = 4.27; SD = 0.75) and that seeing the maps of the others was useful (M = 3.58; SD = 0.58).

The second analysis explored whether the use of the KIA-Tool had an effect on the dependent measures: The questionnaire afterwards showed that the study was more stressful for participants in the control condition (M_C = 3.2; M_E = 2.7; $F(1,27) = 4.66$; MSE = 0.28; $p < .05$), although the experimental condition had more problems regarding the use of the different windows on the desktop (M_C = 1.8; M_E = 2.2; $F(1,27) = 6.25$; MSE = 0.25; $p < .05$), compared to the control groups. This last result was not unexpected, due to the fact that in the experimental condition the participants had to work with two more windows than the control condition. The result before showed that the cognitive load in the control condition was higher than in the experimental condition.

In addition, in the experimental condition the participants stated that the collaboration with each other led to a better overview regarding the relations of the domain compared to the control groups (M_C = 4.0; M_E = 4.3; $F(1,27) = 5.89$; MSE = 0.22; $p < .05$). This could be confirmed by the analysis of the domain knowledge measures: The analysis revealed better performance for the experimental groups regarding the knowledge on domain relations compared to the control groups (M_C = 3.4; M_E = 3.7; $F(1,27) = 3.43$; MSE = 0.21; p = .075). Regarding the domain knowledge performance, the experimental condition gained a higher performance on domain relations that were shared by a participant collaborator dyad, compared to the control groups (M_C = 2.1; M_E = 2.4;$F(1,27) = 4.2$; MSE = 0.14; $p > .05$). This result constitutes evidence for the helpfulness of the KIA-Tool, because the participants were aware of which other collaborator had the same relation knowledge that they had. In addition, the analyses revealed higher performance by the experimental groups with regard to knowledge about information that is linked to concepts: In this context,

the experimental groups gained higher values in knowledge regarding information that is only shared by the other collaborators, that is, the participant himself did not have this information (M_C = 2.6; M_E = 2.9; $F(1,27) = 4.17$; $MSE = 0.41$; $p = .05$). This result also provides evidence of the efficiency of the KIA-Tool: Considering information underlying a concept, participants in the experimental condition did remember more often items that both other collaborators had.

With regard to the problem solving tasks, the experimental groups tended to be more confident that they solved the two tasks correctly, compared to the control group (w.r.t. the pesticide problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.38$; $MSE = 0.47$; $p = .077$; w.r.t. the fertilizer problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.17$; $MSE = 0.57$; $p = .086$). This subjective estimation is partly mirrored in objective results, namely in the group answers given: Regarding the number of correct answers to the pesticide problem, the data did not show a significant difference between the conditions. However, with regard to the reasons given why they chose the correct pesticide the experimental condition was superior to the control condition ($M_C = 0.2$; $M_E = 0.8$; $F(1,27) = 3.36$; $MSE = 0.7$; $p < .1$). Contrarily, regarding the number of correct answers to the fertilizer problem, the experimental condition gained a higher performance compared to the control condition (Pearson-χ^2 (2) = 4.9; $p < .1$). But with regard to the reasons given why they chose the correct fertilizer there was no significant difference between the groups.

5 Conclusion

The presented study demonstrated that computer-supported collaborative problem-solving could be supported by a "knowledge and information awareness" tool (KIA-Tool) that made a group member aware of the knowledge and the corresponding underlying information of the other collaborators. In this study an experimental condition using this tool was compared to a control condition that worked without it. First results of the analysis showed that the participants of the experimental condition evaluated the use of the KIA-Tool as helpful. Comparing the two conditions it could be showed that the study was more stressful for the control condition, although the experimental condition had more difficulties in using the windows. Therefore, the benefit of using a KIA-Tool seems to be large enough to compensate the higher cognitive load caused by the need to use more windows. The analyses also showed that the experimental groups achieved higher performance in both knowledge regarding content information that was only shared by the other collaborators and knowledge regarding relation information that an individual and another collaborator had. In addition, the study demonstrated that using a KIA-Tool was helpful for problem solving performances. The results support hypotheses concerning the support of Web-based collaborative learning and problem solving by enhancing knowledge and information awareness. Further research activities will investigate in more detail the factors that are causative for the efficiency of the KIA-Tool.

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References

Baltes, B. B., Dickson, M. W., Sherman, M. P., Bauer, C. C., & LaGanke, J. (2002). Computer-mediated communication and group decision making: A meta-analysis. Organizational Behavior and Human Decision Processes, 87(1), 156-179.

Bleakley, A., & Carrigan, J. L. (1994). Resource-based learning activities: Information literacy for high school students. American Library Association: Chicago.

Carroll, J. M., Neale, D. C., Isenhour, P. L., Rosson, M. B., & McCrickard, D. S. (2003). Notification and awareness: Synchronizing task-oriented collaborative activity. International Journal of Human-Computer Studies, 58 (5), 605-632.

Christiansen, N., & Maglaughlin, K. (2003). Crossing from Physical Workplace to Virtual Workspace: be AWARE! In D. Harris, V. Duffy, M. Smith & C. Stephanidis (Eds.), Proceedings of HCI International Conference on Human Computer Interaction 2003 (pp. 1128-1132). Hillsdale, NJ: Erlbaum.

Clark, H. H., & Brennan S. E. (1993). Grounding in communication. In R. E. Baecker (Ed.), Readings in groupware and computer-supported cooperative work assisting human collaboration (pp. 222-233). San Mateo, CA.: Morgan Kaufman

Cox R. (1999). Representation construction, externalised cognition and individual differences. Learning and Instruction, 9, 343-363.

Dewiyanti, S., Brand-Gruwel, S., & Jochems, W. (2005). Learning together in an asynchronous computer-supported collaborative learning environment: The effect of reflection on group processes in distance education. Paper presented at Earli, 2005, Nicosia, Cyprus.

Endsley, M. (1995). Toward a theory of situation awareness in dynamic systems. Human Factors and Ergonomics Society, 37(1), 32-64.

Fjermestad, J. (2004). An analysis of communication mode in group support systems research. Decision Support Systems, 37(2), 239-263.

Gross, T., Stary, C., & Totter, A. (2005). User-Centered Awareness in Computer-Supported Cooperative Work-Systems: Structured Embedding of Findings from Social Sciences. International Journal of Human-Computer Interaction, 18, 323-360.

Janssen, J., Erkens, G., Jaspers, J., & Broeken, M. (2005). Effects of visualizing participation in computer-supported collaborative learning. *Paper presented at Earli*, 2005, Nicosia, Cyprus.

Kollar, I., Fischer, F., & Slotta, J. D. (2005). Internal and external collaboration scripts in webbased science learning at schools. In T. Koschmann, D. Suthers, & T. -W. Chan (Eds.), Computer Supported Collaborative Learning 2005: The Next 10 Years (pp. 331-340). Mahwah, NJ: Lawrence Erlbaum.

Koschmann, T. (2002). Dewey's contribution to the foundations of CSCL research. In G. Stahl (Ed.), Computer support for collaborative learning: Foundations for a CSCL community: Proceedings of CSCL 2002 (pp. 17-22). Boulder, CO: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Salomon, G. (1992). What does the design of effective CSCL require and how do we study its effects?. SIGCUE Oulook, 21, 62-68.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning. In R. K. Sawyer (Ed.), Cambridge Handbook of the Learning Sciences (cpp. 409-426). Cambridge: University Press.

Stasser, G., Vaughan, S. I., & Stewart, D. D. (2000). Pooling unshared information: The benefits of knowing how access to information is distributed among members. Organizational Behavior and Human Decision Processes, 82, 102-116.

Suthers, D. D. (2005). Technology affordances for intersubjective learning: A thematic agenda for CSCL. In T. Koschmann, D. D. Suthers & T. W. Chan (Eds.), Computer Supported Collaborative Learning 2005: The Next 10 Years! (pp. 662-672). Mahwah, NJ: Lawrence Erlbaum Associates.

Tergan, S.-O.. (2005). Digital concept maps for managing knowledge and information. In S.-O. Tergan, & T. Keller (Eds). Knowledge and information visualization. Searching for synergies (pp. 185-204). Lecture Notes in Computer Science LNCS 3426. Springer: Berlin Heidelberg New York.

Tergan, S.-O., & Keller, T. (Eds.) (2005). Knowledge and information visualization: Searching for synergies. Lecture Notes in Computer Science LNCS 3426. Springer: Berlin Heidelberg New York.

Tergan, S.-O., Keller, T., & Burkhard, R. (in press). Visualizing Knowledge and Information with Digital Concept Maps: Rationale, Goals, and Introduction. Information Visualization, 5(3).

Thompson, L. F., & Coovert, M. D. (2003). Teamwork online: The effects of computer conferencingon perceived confusion, satisfaction and postdiscussion accuracy. Group Dynamics, 7(2), 135-151.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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CONCEPTUALIZING PEDAGOGICAL CHANGE: EVALUATING THE EFFECTIVENESS OF THE EPS MODEL BY USING CONCEPT MAPPING TO ASSESS STUDENT CONCEPTUAL CHANGE

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Abstract. The research presented here is from a three-year study that uses concept mapping to assess change in student conceptual understanding in science at the undergraduate level. The fundamental question being addressed is, "To what extent do pedagogical changes such as adaptation of an environmental problem-solving (EPS) model influence student understanding in undergraduate science?" This study is part of a National Science Foundation (NSF)-initiative to improve the teaching of science at the undergraduate level, and to study changes in teaching practice and student learning that result from this improvement. NSF-funded regional summer workshops (RWP) trained 400 faculty in facilitating local environmental problem-solving experiences, field/laboratory exercises, and cooperative learning environments for students at their home universities. One and two years following workshop attendance, eight faculty members were selected from this pool of attendees for in-depth analysis of student learning in a selected course they taught. The study used qualitative and quantitative analysis of concept mapping data to assess student conceptual understanding across a wide range of institutions and academic disciplines. The sample population consisted of a total of 79 students, 59 science majors and 20 non-majors. Results suggest that the adaptation of the EPS model was effective in increasing student conceptual understanding, as measured by concept maps. The greatest determinant of increased conceptual understanding over the course of a semester was the student's self-report of approaches to learning and studying. Approaches to learning, in turn, were reflective of differences in the quality of student concept maps. Concomitantly, the student concept maps reflected student gains in content and depth over a semester with respect to an expert map. The results also suggest that teaching styles, particularly the level of faculty-student interaction, are associated with student gains in depth of understanding.

1 Introduction

1.1 Regional Workshop Project (RWP) and its Goals

This study is tied to a National Science Foundation (NSF) – funded national dissemination project – The Regional Workshops Project (RWP) that sought to train 400 undergraduate science, technology, engineering, and mathematics (STEM) faculty from across the United States. The RWP aimed to train faculty who 1) Create and deliver undergraduate STEM courses using environmental problem-solving as an integrative, challenging, effective way to engage students in undergraduate STEM courses, 2) Use concepts and field/laboratory techniques suitable for teaching undergraduates how science is done in the real world, and 3) Use research-based knowledge of how to assess student learning and support faculty capacity for development. Using local environmental problems, the RWP Model provides faculty with techniques and practices to improve undergraduate STEM instruction and thereby enhance contexts for STEM education.

1.2 Assessing Student Achievement (ASA) Project

The present study compared classroom observations of pedagogy with concept mapping as an assessment tool to study the effect of faculty teaching methods in undergraduate science courses on student learning. To this end, students in selected courses at colleges and universities across the United States were chosen for in-depth analysis of change in conceptual understanding over the course of a semester. Individual concept maps were analyzed to determine whether students had integrated new science concepts with existing concepts and improved in depth of conceptual understanding. As student learning is dependent on the goals of the instructor, the researchers also compared student maps with respective faculty maps to determine the instructor's learning goals and analyze the extent to which the students achieved the instructor's goals.

1.3 Environmental Problem-Solving Model

The objectives of this study was 1) to examine teaching methods, classroom culture, and student learning in undergraduate science courses taught by RWP faculty who adapted an Environmental Problem-Solving (EPS) approach to teach undergraduate STEM courses, and 2) to examine how innovative teaching approaches interact with individual and classroom variables to affect change in student conceptual understanding in science. Environmental Problem-Solving (EPS) is a model for science education that melds classroom instruction, field and

laboratory techniques, and cooperative learning (Haynes, 1991). The EPS model has been used successfully for undergraduate and graduate courses in biology, chemistry, geology, engineering, and environmental science across the United States. The RWP uses environmental impact analysis as a unifying theme to bring together the disparate techniques used by participants into a holistic, relevant problem-solving context. This provides a model to teach undergraduates how science is really done (learning and applying knowledge in a problem-solving context, "hands-on", teamwork) while students work to address real, local environmental problems.

Adaptation of the EPS model and subsequent student conceptual understanding is expected to vary depending on which key factors are in place in a particular classroom. Conceptual learning is encouraged through problem-based activities that require critical thinking. However, the degree to which activities requiring critical thinking are applied can depend on faculty beliefs as well as institutional structure. In addition, individual students will differ in individual receptivity to assignments requiring critical thinking skills (Kinchin, 2000). By analyzing interview and observational data, and subsequent concept maps created from this data, the current research addressed the extent to which a discrepancy exists between faculty expectations for students and actual student learning outcomes when a science course is adapted to follow an EPS-based model.

2 Theoretical Perspectives

2.1 Concept Mapping as a Research Tool

Competence in a domain of knowledge is defined by knowledge that has highly integrated structure around central concepts (Glaser and Bassok, 1989). Concept maps are visual representations of meaningful relationships between concepts and linking propositions. They offer an effective way by which to assess student understanding by providing evidence of the quality and accuracy of propositions applied by the individual in the process of higher-order thinking. Concept maps provide a "workable representation" of knowledge and can be used to infer accuracy and depth of knowledge.

Since expertise in a knowledge area is represented by the interconnectedness of knowledge, we chose to construct expert concept maps from structured interviews with faculty participants. We used each faculty map as a benchmark representing key concepts and expectations emphasized in the target undergraduate STEM course. We then compared student concept maps to faculty maps at the beginning and end of a semester in order to assess change in student conceptual understanding compared to expert organization of knowledge (Ruiz-Primo et. al., 2001). In addition, we assessed the quality of individual student maps, based on qualitative criteria, in order to evaluate changes in content, accuracy, depth of understanding, and organization of knowledge from the beginning to the end of each course.

2.2 Meaningful Learning

The value of using concept mapping to assess change in conceptual understanding is based on the idea of meaningful learning. Within science education, it is widely accepted that prior knowledge is a key factor that influences learning (Clifton and Slowiaczek, 1981). Meaningful learning, originally proposed in Ausubel's assimilation theory (1963), is in direct contrast to rote learning and involves an act of relating new knowledge to relevant concepts and propositions that are already known. Meaningful learning also involves the ability to link new concepts and their meanings to broader and more comprehensive concepts. In order for meaningful learning to occur, instructional methods have to discourage rote learning by stimulating critical thinking.

2.3 Problem-Based Learning-EPS Model

EPS courses are expected to facilitate high quality learning experiences through meaningful, problem-based activities. Problem-based learning environments center instruction around a unifying theme or problem that is relevant to the local community. Structuring science courses around a relevant problem to be solved allows students to see connections to the "real world" and experience science as it is actually practiced. Problem-based learning activities may include a series of integrated field and laboratory exercises, individual assignments addressing local environmental problems, and student written or oral presentations on their findings. The EPS environment provides an interactive setting for students to discuss, debate, build, and present their understanding and hear the perspectives

of their peers. As students work together solving problems, ideas are shared and refined, and the experiences translated into robust, usable knowledge (Brown, Collins & Deguid, 1991).

Group collaboration allows students to negotiate, reflect upon, and evaluate each other's understandings. As students gain more control in the learning process, they begin to participate consciously in the classroom-culture. Through "problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86), students make meaningful connections and their conceptual understanding develops. Meaningful learning, originally proposed in Ausubel's assimilation theory (1963), involves an act of actively relating new knowledge to existing concepts.

The teaching-learning environment present in undergraduate science courses represents a broad range of potential influences on student learning. Aspects of course design and organization, teaching and assessing course content, staff-student relationships, and individual variables present in a particular student cohort interact to affect student-learning experiences (Entwistle et. al., 2002). Course design and organization can impact level of student engagement and interest as well as depth of understanding of key concepts. Likewise, teacher beliefs and subsequent methods of practice will affect implementation of course content and the development of supportive student-teacher relationships. Individual differences in student approaches to studying, as well as disparate environments and prior knowledge and skills, can influence student receptivity to course contexts. Finally, sustainability of change in teaching practices depends not only on faculty attitudes and perceptions of disciplinary and student variables, but also require departmental policy and priorities compatible or aligned with the reform (Coburn, 2003).

3 Methodology and Materials

Our research design employed a mixed-methods approach to examine the extent of implementation of EPS techniques and their resulting impact on student learning using a select group of faculty participants varying by region, type of institution, and academic discipline. Faculty chosen for participation were selected from a pool of RWP participants. Student and faculty interviews, classroom observation data using the Reformed Teachers Observation Protocol (RTOP, Sawada & Pinburn 1999), concept maps, and questionnaires measuring student learning and studying approaches (LSQ, Entwistle et. al., 2002) provided a rich description of the teaching-learning environment in faculty participants' classrooms.

Site visits were conducted at the academic institution of each participant faculty for one or two semesters (Table 1). Each group of students enrolled under a participant faculty in a given semester was defined as a cohort. Some of the participant faculty taught the same course during different semesters or in different years and so had more than one cohort of students. Each cohort was visited at the beginning and end of their semester. Prior to each visit, the LSQ was administered to each cohort of students to provide information on individual approaches to studying. The differential between the deep and learning strategies reported on the LSQ was used to group students as deep, mixed or surface learners. Student participation in the study was voluntary. All students in a given cohort were administered the LSQ by their faculty, but not all students chose to participate in the study. Faculty interviews were conducted during the first site-visit to generate an expert map based on the faculty's curricular goals for their student cohort. Classroom observations were conducted using the RTOP. Student conceptual understanding was measured using concept maps, constructed by the authors using data from semi-structured interviews with students. Student maps reflected levels of understanding of key concepts and concept relationships as identified by each faculty. For a detailed description of methods and techniques used for construction and analysis of concept maps, refer to Cassata & Himangshu (2005).

Two different researchers individually generated a subset of the maps to ensure inter-rater reliability. In addition, each map was scored using a set of criteria agreed on by the members of the research group. The reliability of scoring was established by calculating Crohnbach's alpha coefficient, for terms, misconceptions, and cross-links, on student maps, scored independently by two researchers. A high degree of correspondence of inter-rater consistency was observed (0.83 – 0.90) between the pre- and post-student maps. The scoring rubric considered data that related to students' understanding (or lack) of relationships between concepts. The validity of the student concept maps was reflected in the high correspondence (>95%) between verbally expressed declarative knowledge (data from student interviews) and the researcher-generated maps for each student. In addition, faculty maps were

checked with individual faculty to ensure accurate representation of faculty curricular goals. Data from both qualitative and quantitative analyses was then compared and analyzed using SPSS 13.0 software.

4 Results

The sample population consists of 79 students from 11 classrooms taught by seven different faculty, of which 59 (75%) were science majors (including biology, chemistry, and environmental science) and 20 (25%) students were non-majors.

FACULTY	Number of Students	STUDENT DISTRIBUTION BY LEARNING STYLES		
(Number of Cohorts)	(N)	Deep Approach (%)	Mixed Approach (%)	Surface Approach (%)
Faculty A (2)	17	6	59	35
Faculty B (2)	13	23	77	0
Faculty C (2)	9	0	100	0
Faculty D (2)	19	10	68	22
Faculty E (1)	7	0	57	43
Faculty F (1)	4	0	50	50
Faculty G (1)	10	100	0	0

Table 1: Distribution of Student Learning Styles by Faculty

Table 1 summarizes the distribution of student learning strategies for different cohorts, as reported on the LSQ. Two out of eleven cohorts had only mixed and surface learners (E & F) whereas both B cohorts had no surface learners and both A & D cohorts had all three groups of learners. Students in cohorts B, C and G tended to use significantly fewer surface-level learning strategies since these cohorts had no surface-learners but consisted of deep and/or mixed learners (Table 1). Students in cohorts A, D, E and F on the other hand, were evenly distributed by mixed and surface learning approaches and tended to use surface-level strategies to a greater degree. This correlated to the analysis of student post-maps for each cohort (Table 3).

Each class was examined on dimensions of instructional strategies and activities, integration of new concepts into familiar contexts, level of student-student and student-teacher communication, encouragement of active student participation, and level of support provided by teacher to enhance student investigations. As shown in Table 2, comparison of the classrooms on the variables of interest revealed that all faculty incorporated aspects of the EPS model to differing degrees in their teaching practice, by 1) connecting concepts to “real/local” issues, 2) providing a highly or moderately interactive setting where student input was encouraged, and 3) by emphasizing peer collaboration as an integral part of the course.

Student concept maps were compared with expert (faculty) maps to measure change in depth of understanding over a semester. Concept maps were analyzed for attainment of main ideas, presence or absence of misconceptions, tendency to make connections between concepts, and level of conceptual organization. Table 3 gives a summary of preliminary results highlighting that the majority of students in each cohort attained the main ideas of the course as specified by individual faculty.

	Instructional Strategies	New Concepts	Student to Student Communication	Teacher to Student Communication	Teacher Encouragement	Teacher Support
Faculty A (Environmental Science)	Use of website	Related current events (Clean Air Act, EPA rules) to course content	Occasionally, teacher-facilitated	Prompting students to express ideas in class, working with students on projects outside of class	Helps students continue and expand on thoughts, asking students to express personal views based on actual environmental data	Uses several examples of actual data to clarify points (from EPA website)
Faculty B (Environmental Science)	Use of website, whiteboard, video and power point	Related current events (relationship between community and environment, emphasized merits of education vs. enforcement) to course content	Regularly, through discussions in class and in-class group projects	Relaxed but focused atmosphere, stimulates and facilitates discussion in and out of class	Encouraged students to express different viewpoints on environmental issues, guides students toward logical conclusions	Uses several examples of actual data to clarify points (from USDA and Canadian agricultural department)
Faculty C (Biology)	Use of Power point and blackboard	Related content with a variety of relevant examples	Regularly, through discussions in class and in-class group projects	Relaxed but focused atmosphere, stimulates and facilitates discussion in and out of class	Encouraged students to come up with their own answers, guided group discussion	Uses examples relevant to everyday life (leaky mitochondria and runners' wall)
Faculty D (Biology)	Use of Power point and blackboard	Used a inter-related framework to explain organ functions	Regularly through group lab projects	Relaxed atmosphere, encourages questions	Encouraged students to use the web to find information and share during group work	Uses examples (draws figures on board)
Faculty E (Analytical Chemistry)	Use of Power point and blackboard	Related to standards for Chemical Society	Occasionally, teacher-facilitated	Focused atmosphere, faculty encouraged alternate modes of thinking	Participated as a resource person to guide student questions	Uses several examples of actual data to clarify points (from ACA website)
Faculty F (Environmental Chemistry)	Use of website and blackboard	Related to local events (Paper Mill; Hurricane in NC)	Occasionally, teacher-facilitated and through group lab projects	Limited discussion during project work	Prompted students to express ideas regarding local environmental issues	Uses several examples of actual data to clarify points (regarding local Paper Mill)
Faculty G (Environmental Science)	Use of Power point and white board	Used examples and connected concepts	Faculty encouraged interpretation of evidence, alternate solutions	Relaxed atmosphere, faculty was patient and clarified student questions	Encouraged students to think aloud through their answers	Used local examples of pollution (ASARCO)

Table 2: Level of Faculty Interaction as Measured by Classroom Observations and RTOP

Analysis of student maps suggests that the quality of maps correlated to student approaches to learning and studying, as measured by the LSQ. Average gain from beginning to end of semester in number of terms and linkages between concepts was calculated. Student-cohorts A and D (Table 3), largely using a mixed approach to studying, incorporating surface and deep strategies, showed the greatest improvement at 70% in overall quality of conceptual understanding between pre- and post-test (Table 3). However, when grouped with cohort G, which consisted of

100% deep learners (Table 1), only 60.87% of the moderately-high cohorts showed improvement in quality of post-maps. This is due to the pre-maps of the deep learners in cohort G already having good organization and linkages between the concepts. Consistently, student maps from cohorts E and F using a greater degree of surface approaches to learning showed only 54% of overall improvement in map quality (Table 3). Cohorts from the highly interactive faculty (B & C) that had no surface learners (Table 3) showed maximum gain in content and depth of understanding represented by the quality of their post-maps (Table 3).

Student Cohorts Belonging to Faculty:	Level of Faculty Interaction	Student Number (n)	% Students with Main Ideas	% Students with Misconceptions	% Students with Improved Organization	Average Gain in Terms (%)	Average Gain in Links (%)	% Surface Learners
B & C	High	22	86	34	62.5	29	22	0
A & D & G	Moderately High	46	85	19.5	60.87	18	15	22
E & F	Moderate	11	81.5	21.5	54	15	15.16	41.5

Table 3: Correlation of Student Post-Maps with respect to Faculty Teaching Style

In addition, student concept maps were analyzed in comparison to faculty maps. Students of Faculty A, D, E and F on the whole, demonstrated lower gains in conceptual understanding, measured by gain in number of links between concepts from beginning to end of semester, compared to students of Faculty B and C. Students varied in the degree to which their conceptual understanding paralleled that of the expert map.

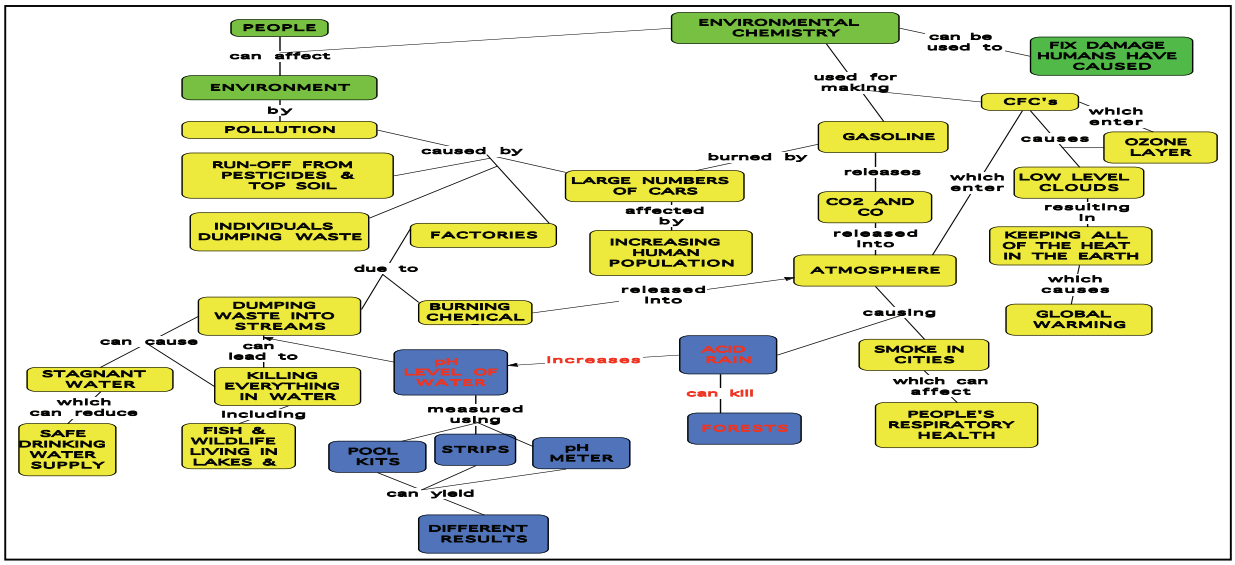


Figure 1. Example of a student pre-map from cohort F showing a misconception regarding pH and acid rain. The different colors correspond to commonality of concepts with respect to cohort F's expert map (not included)

Gain in understanding was represented by the difference between the percent of student linkages with respect to the faculty map from the beginning to the end of the semester. The maximum gain observed in this cohort was 29% from pre- to post-test. Between types of classes, students in highly interactive classes tended to exhibit a higher percentage of gain than students in moderately interactive classes. The apparent high degree of misconceptions in student maps from the highly interactive cohorts is due to a third of surface learners in this cohort that were using mainly surface strategies for learning (Table 3). In comparison, equivalent degrees of the moderately-high

interactive cohorts (19.5%) and moderately active cohorts (21.5%) showed presence of misconceptions although only a fourth of that population used surface-level approaches to learning (Table 3).

According to the RTOP analysis (Table 2), all seven faculty facilitated open communication with the students through class discussion, group work, teacher proximity to students, and individual student-teacher interactions. In addition, all seven faculty related course material to real-world applications by using visual tools such as power point presentations as an interactive medium of instruction. In addition, all seven faculty emphasized critical thinking through adoption of the scientific process to assignments and classroom activities. In summary, all seven faculty applied some aspects of the EPS model to their teaching practices. Analysis of student maps in comparison to faculty maps reflected gains in number of concepts as well as depth of understanding (represented by linkages between concepts) between pre- and post-concept maps for the majority of students. Statistical analysis was conducted to calculate Pearson's correlation coefficient for the relationship between the change in terms and change in links between student pre- and post-concept maps found a strong positive correlation ($r(77) = 0.926$, $p<0.01$), indicating a significant linear relationship between content knowledge and increase in depth of understanding as measured by the change in terms versus change in links represented in the student concept maps. Irrespective of the level of faculty interaction, 88% of all students' demonstrated gain in conceptual understanding as measured by the concept maps.

Consistent with the above results, correlation analysis between faculty interaction from high (Faculty B and C) to moderate or moderately-high (Faculty E, F, A, D and G) also showed a significant relationship between content knowledge and increase in depth of understanding as measured by the change in number of terms versus change in number of links represented in the student concept maps. Pearson's correlation coefficient for the relationship between the change in number of terms and change in number of links between student pre- and post-concept maps for high to moderate faculty interactions found strong correlations ($r_h (2) = 0.921$, $p<0.01$) and ($r_m (5) = 0.750$, $p<0.01$), respectively. What this suggests is that the relationship between an interactive pedagogical style and organization of the faculty map is robust and influences student conceptual understanding. Thus, this method of using concept maps to correlate the effect of pedagogical change on student learning helps triangulate factors that are important for enhancing student conceptual knowledge in the undergraduate science classroom.

5 Conclusions and Future Implications

Data from this study indicates that student approaches to learning and faculty pedagogy are both important factors that influence student understanding. In addition concept maps, by providing a visual representation of knowledge organization, enable faculty to examine key processes that help students make meaning of scientific concepts and integration of the concepts into pre-existing knowledge bases. Faculty member checks also highlighted the differential between faculty expectations for their students and the reality of student understanding. These results suggest the importance of designing assessment methods to match curricular changes and have broad implications for improving undergraduate science education. We anticipate that our study will provide a model for future studies that seek to use concept mapping as novel tool for monitoring faculty pedagogical change by assessing change in student conceptual understanding.

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7 References

Ausubel, D.P. (1963). The psychology of meaningful verbal learning. New York: Grune & Stratton.

Brown, J.S., Collins, A., and Duguid, P. (1991). Situated cognition and the culture of learning. In M. Yazdani and R.W. Lawler (Eds.), *Artificial Intelligence and Education*, Vol. 2. Norwood, NJ, USA: Ablex Publishing Corp.

Cassata, A.E., Himangshu, S. and Iuli, R.I. (2005). What is happening in science classes with respect to student learning? 78th. NARST International Conference Proceedings, Dallas, Texas, April 4-7, 2005.

Clifton, C. & Slowiaczek, M.L. (1981). Integrating new information with old knowledge. *Memory and Cognition*, 9,142-148.

Coburn, C.E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. Educational Researcher, 32(6), 3-12.

Entwhistle, N., McCune,V., and Hounsell, J. (2002). Approaches to studying and the perceptions of university teaching-learning environments: Concepts, measures and preliminary findings. ETL Project, Occasional Report 1. [On-line]. Available: http://www.tlrp.org

Glaser, R. & Bassok, M. (1989). Learning theory and the study of instruction.*Annual Review of Psychology, 40*,631-666.

Haynes, J.M. (1991). New curricula developed by undergraduate faculty participants in the GLRC-NSF summer practicum. *Final reports to the National Science Foundation by the Great Lakes Research Consortium Summer Practicum for Applied Environmental Problem-Solving* 252 p.

Kinchin, I.M. (2000). Concept mapping in biology. Journal of Biological Education, 34(2), 61-68.

Ruiz-Primo, M.A., Schultz, S.E., Li, M., and Shavelson, R.J. (2001). Comparison of the reliability and validity of scores from two concept mapping techniques. *Journal of Research in Science Teaching, 38*(2), 260-278.

Swada, D., Piburn, M., Falconer, K., Turley, J., Benford, R., and Bloom, I. (2000). Reform Teaching Observation Protocol Technical Report IN00-1. Arizona State University.

Vygotsky, L.S. (1978). *Minds in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

CONÉCTATE AL CONOCIMIENTO: UNA ESTRATEGIA NACIONAL DE PANAMÁ BASADA EN MAPAS CONCEPTUALES

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Resumen. Plantea la experiencia de Panamá que adoptó una estrategia nacional basada en Aprendizaje significativo y mapas conceptuales para el sistema público de educación básica, a través de un proyecto denominado Conéctate al Conocimiento. Establece como una red nacional de colaboración en la construcción de conocimiento. Involucra 1,000 escuelas en un período de cinco años. En sus primeros dos años de operación, el proyecto ya ha atendido, cerca de 250 escuelas con procesos de formación para sus docentes ofreciendo 140 talleres en los que participaron 3,200 docentes, directores y supervisores. Un beneficio que se extiende aproximadamente a 90,000 niños y sus familias. Conéctate propicia un espacio inédito de observación y experimentación sobre las teorías de aprendizaje significativo y sus herramientas, en una dimensión de escala nacional.

1 Escenario

1.1 Panamá Inteligente

Para la generación que inicia el milenio, la sociedad demanda formas nuevas de aprendizaje, desplazando la atención desde un pasado anclado en la certidumbre y los resultados tangibles, hacia un futuro que exige coexistencia con la incertidumbre, la complejidad, el cambio y la ambigüedad. Se requiere, pensamiento flexible, no lineal, conectando factores, más allá de la simplicidad de cuando una sola respuesta era la correcta.

Bajo estas aspiraciones se diseñó una estrategia nacional, denominada *Panamá Inteligente*, de la cuál su proyecto principal es *Conéctate al Conocimiento*. Ha contado con la participación personal del Presidente de la República, quien ha otorgado prioridad en su ejecución, y da seguimiento a través de la Secretaría de la Presidencia para la Innovación Gubernamental, creada para desarrollar iniciativas de esta naturaleza.

Conéctate, establece una red nacional de conocimiento y colaboración entre las escuelas participantes, creando una comunidad de aprendizaje. Busca transformar el tradicional ambiente de memorización y repetición de información, en un proceso de construcción de conocimiento y desarrollo de poderosas habilidades acordes con las exigencias del presente. Se crea en las escuelas públicas participantes, un *Aula de Innovación*, dotada de recursos tecnológicos, para apoyar todo el proceso. Se comprendió desde un inicio, que a diferencia de otras propuestas, la transformación debía comenzar desde el aula misma, y trabajar formando maestro por maestro.

Para su ejecución, se vinculó un grupo interdisciplinario de profesionales, denominado –Facilitadores. Se capacitaron en los enfoques de aprendizaje significativo, y de mapas conceptuales. Estos facilitadores, a su vez, forman a maestros de las escuelas participantes, brindan asesoría directa en sus aulas, y apoyan su aplicación con los niños. Un equipo consultor asegura la transferencia de métodos y herramientas, interactuando con maestros, directores, supervisores, coordinadores regionales y autoridades educativas.

La esencia del proyecto implica que se deben generar cambios en la cultura educativa, donde se asuman la innovación y las nuevas tecnologías como estrategias de desarrollo y progreso. Se trata de cambios que procuran, un enfoque altamente participativo entre todos los integrantes, sean estos dirigentes, supervisores, directores, docentes o alumnos, todos asumidos como aprendices. Se trata, de innovar sobre el enfoque tradicional basado en autoridad, jerarquía y rigidez, que predomina en sistemas educativos.

Parte de un severo cuestionamiento sobre los materiales que utilizan, sobre los métodos en que persisten y sobre el alcance de los contenidos. Permite establecer un enfoque deliberado en la formación para docentes y para dirigentes, en la configuración de redes de colaboración sin fronteras entre instituciones educativas enfocadas intensamente en la calidad, en la apertura en su oferta de servicios, y en la innovación, para conseguir la excelencia.

El esfuerzo debe orientarse hacia romper, con un cambio que va desde el aula hasta los niveles directivos, con los modelos mentales tradicionales que promueven procedimientos de control basados en la jerarquía y la implementación de procedimientos y criterios de evaluación propios de la preservación del sistema tradicional. Bajo la orientación de la Secretaría de la Presidencia para la Innovación Gubernamental, se exploraron las opciones metodológicas y se encontró que la estrategia de aprendizaje significativo y las herramientas de mapas conceptuales cumplían con los aspectos considerados como claves para el desarrollo de los niños en Panamá.

1.2 Conectividad y competitividad

Simultáneamente, se examinaron los temas de la competitividad internacional propuestos por el Foro Económico Mundial[1] y la necesidad de desarrollar nuevos tipos de habilidades, y las ventajas de Panamá no aprovechadas en este contexto. Se observa la Conectividad como un factor clave para un país ubicado estratégicamente en el medio del hemisferio americano, centro internacional de comercio y finanzas, con amplio atractivo turístico. Con una extensión de territorio y tamaño de población que permite una apropiada inserción en los circuitos globales de las economías basadas en servicio y en conocimiento.

La OECD a través de programas como PISA[2] ha puesto de presente la necesidad de desarrollar nuevos tipos de habilidades que preparen a los individuos para escenarios de alta conectividad global, preocupación que se manifiesta en la Cumbre Mundial de la Sociedad de Información – WSIS - cuando adopta su declaración final: "*Para que la sociedad actual no herede a la siguiente las desigualdades del presente, la respuesta universal es una sola: Conectar a los niños*". [3]

1.3 Experiencias de escala nacional

El sistema educativo en Panamá exhibe problemas importantes, que han propulsado con frecuencia proyectos de reforma. Algunos de ellos, dirigidos a la dotación de computadoras para las aulas de clase, precisamente adoptando una política tecnocentrista muy criticable[4]. Esos esfuerzos generaron un doble fracaso: por un lado, no pudieron lograr sus metas, particularmente con un enfoque metodológico coherente, y por el otro, se perdieron las oportunidades de inversión y el entusiasmo que estas iniciativas despiertan.

En las reformas propuestas, se ha intentado establecer proyectos de integración curricular, pero no fueron apoyados por la tecnología, que tomó el rumbo de ofrecer capacitación en informática de oficina a los maestros, con la aspiración de que esas herramientas pudieran influir en la calidad final de las clases.

Conéctate al conocimiento se ha propuesto establecer la Red con la participación de 1,000 escuelas en un período de 5 años, lo cuál significa un importante porcentaje del total de los establecimientos, preparando una proporción significativa de los maestros de cada escuela, iniciando por los últimos tres grados de la primaria. Otros grados y niveles se están vinculando en las escuelas por extensión de la formación que han recibido sus maestros. Fases superiores del proyecto cubrirán estos niveles. Se han atendido 250 escuelas, impartiendo 140 talleres para la formación de más de 3,200 maestros, quienes influyen en la formación de 90,000 niños aproximadamente. Este es un esfuerzo realizado por más de 30 facilitadores en un período de año y medio. Adicionalmente, se han realizado visitas a un número importante de las escuelas, para realizar funciones de acompañamiento, seguimiento y asesoría.

El proyecto representa también la oportunidad de dar seguimiento y establecer un observatorio internacional sobre los impactos, posibilidades, problemas y aprendizajes en una escala nacional. Fases futuras esperan atender a las escuelas normales y facultades formadoras de docentes, así como niveles de secundaria y proyectos especiales.

2 Enfoque y Diseño

El proyecto adopta un enfoque constructivista para el aprendizaje, claramente inspirado en las teorías de Piaget, y su diseño ha planteado con firmeza ese mismo enfoque en los procesos para la formación de los docentes y en la forma como se espera observar su efecto con los niños. Ausubel aporta desde el enfoque teórico dos elementos que apoyan y justifican decisiones que son mayores para un sistema educativo nacional: de un lado, el aceptar que lo más importante en el aprendizaje es lo que el individuo ya sabe, y del otro, que todo nuevo conocimiento se construye a partir de las relaciones con el pre-existente.

Ausubel lo resume así: "Si tuviese que reducir toda la psicología educativa a un solo principio, enunciaría este: El factor más importante que influye en el aprendizaje es lo que el alumno ya sabe. Averígüese esto y enséñese consecuentemente" (Ausubel & Novak, 1978).

Se introduce entonces una noción que es central al proyecto Conéctate: Aprendizaje significativo. Acontece cuando una nueva información "se conecta" con un concepto relevante pre existente en la estructura cognitiva, esto implica que, las nuevas ideas, conceptos y proposiciones pueden ser aprendidos significativamente en la medida en que otras ideas, conceptos o proposiciones relevantes estén adecuadamente claras y disponibles en la estructura cognitiva del individuo y que funcionen como un punto de "anclaje" a las primeras.

2.1 Mapas conceptuales

La interacción con el Institute for Human and Machine Cognition propulsó la asesoría científica de los doctores Alberto Cañas y Joseph Novak, de forma que Mapas Conceptuales se afirma como la herramienta principal que maestros, niños y escuelas adoptan para generar la innovación y propiciar aprendizaje significativo. El mismo Dr. Novak propone: "Con frecuencia, en escuelas y otras organizaciones, la gente y las ideas que son innovadoras son amenazantes, resultando en una coalición de fuerzas que silencian o remueven la amenaza"(Novak, 1998).

Para Panamá, un enfoque interesante se refiere a cómo el aprendizaje significativo es poderoso y faculta a las personas. Concluye el Dr. Novak también: "El conocimiento que hemos aprendido de manera significativa, el que hemos construido desde la unión de nuestras acciones, sentimientos y pensamiento consciente, es el conocimiento que controlamos" (Novak, 1998).



Figura 1. Imágenes de Conéctate: Dr. Cañas, facilitadotes, maestros y estudiantes.

Una asesoría de especial contribución al proyecto ha sido la de contar con el Dr. Alberto Cañas y su equipo en el IHMC quienes han dirigido los procesos para a formación de un grupo profesional local en entendimiento intelectual de la dimensión del cambio y la innovación que significa una estrategia basada en mapas conceptuales, y particularmente, en el manejo de las herramientas CmapTools (Cañas et al., 2004) para construir y colaborar con mapas conceptuales.

El proyecto estableció una definición de diseño basada en tres elementos clave:

- Aprendizaje significativo
- Proceso para formación apoyado por un grupo de facilitadores
- Aulas de Innovación y Red Nacional

El grupo de facilitadores representa intencionalmente una alta diversidad en profesiones, culturas, regiones y experiencia. Es una enorme riqueza, y demanda alta interacción. El otro atributo de los facilitadores es el de aportar un mirada innovadora a los procesos, incluso dentro del mismo proyecto Conéctate.

Este Grupo puede ser visto con tres perspectivas de aporte: formación, acompañamiento y diseño.

Formación. Enfoca la calidad de los talleres para docentes y directores, contenido, recursos, materiales, metodología organización y programa de trabajo, innovaciones y mejoras.

Acompañamiento. Da seguimiento en las escuelas del avance en la formación de los docentes, del proceso de implantación del proyecto en el interior de la escuela, y de la calidad del trabajo de representación de conocimiento y de colaboración en curso. Protocolo y reporte de las observaciones y banco de datos para seguimiento general del proyecto. Propone evaluaciones e intencionalmente actúa en función de asesoría y consejería dando confianza a los participantes en la adopción de los nuevos esquemas. .

Diseño. Es la función de innovación que aportan los facilitadores al proyecto, incluye aspectos de estudio profesional y conocimiento sobre las áreas de influencia del proyecto, también incluye aspectos de investigación, estudio y exploración, y aspectos de crecimiento personal, construcción de equipo y colaboración. Se materializa en proyectos de estudio y exploración, compilación de información académica relevante, producción de boletines, perfeccionamiento de guías para talleres, seguimiento y actividades del proyecto.

Los facilitadores representan un enfoque interdisciplinario, que busca aportar una mirada diferente sobre la acción educativa, aceptando la diversidad y promoviendo la flexibilidad. Son un elemento fundamental en la instrumentación de un proceso innovador.

2.2 Formación

El proceso de formación se maneja cuidadosamente, por ser el portador real de las innovaciones y converger en el crítico factor humano, para establecer la diferencia en la adopción apropiada de los nuevos conceptos.

Se realiza, para la formación del grupo de facilitadores, un proceso de inmersión inicial en un taller de tres semanas, en el cuál se involucran ingredientes clave en un formato libre, que se va construyendo en conjunto con la retroalimentación del grupo. Entre los elementos se incluye:

- Noción de los escenarios globales que demandan nuevas habilidades
- Exploración sobre sociedad del conocimiento, competitividad y conectividad
- Manejo directo de procesos de aprendizaje significativo
- Aprendizaje del uso de CmapTools para generar mapas conceptuales
- Exploración de funciones de las herramientas
- Enfoque dirigido a la construcción de conocimiento
- Elementos para la colaboración y redes humanas
- Liderazgo y manejo del cambio
- Enfoques teóricos.

Este proceso ha sido alimentado continuamente por la visita frecuente de expertos en diferentes áreas de atención, de manera que el proceso para la formación de los facilitadores se entiende como de carácter permanente.

Así mismo, el grupo prepara los talleres que se imparten a los maestros supervisores y directores de las escuelas participantes. Colectivamente se construyen los aspectos relevantes a tratar y con frecuencia se revisa el esquema buscando las zonas donde hay menor efectividad o se presentan dificultades. Es un proceso dinámico que se ha venido ajustando con la experiencia práctica, y cambia continuamente. Un mapa de construcción colaborativa refleja en la figura 2, el diseño inicial de las visiones que proponen los mismos facilitadores locales, y evoluciona con los ajustes que emanan de la propia experiencia práctica.

Los maestros de las escuelas asisten a un centro de capacitación establecido por Conéctate, habilitado con los recursos para trabajar con los Mapas Conceptuales y los demás elementos. Se procura un ambiente de respeto y

familiaridad, que genere la confianza y el entusiasmo necesarios para adoptar dos cambios simultáneos: El dominio de tecnologías y herramientas, y el nuevo enfoque de aprendizaje significativo llevado a la práctica.

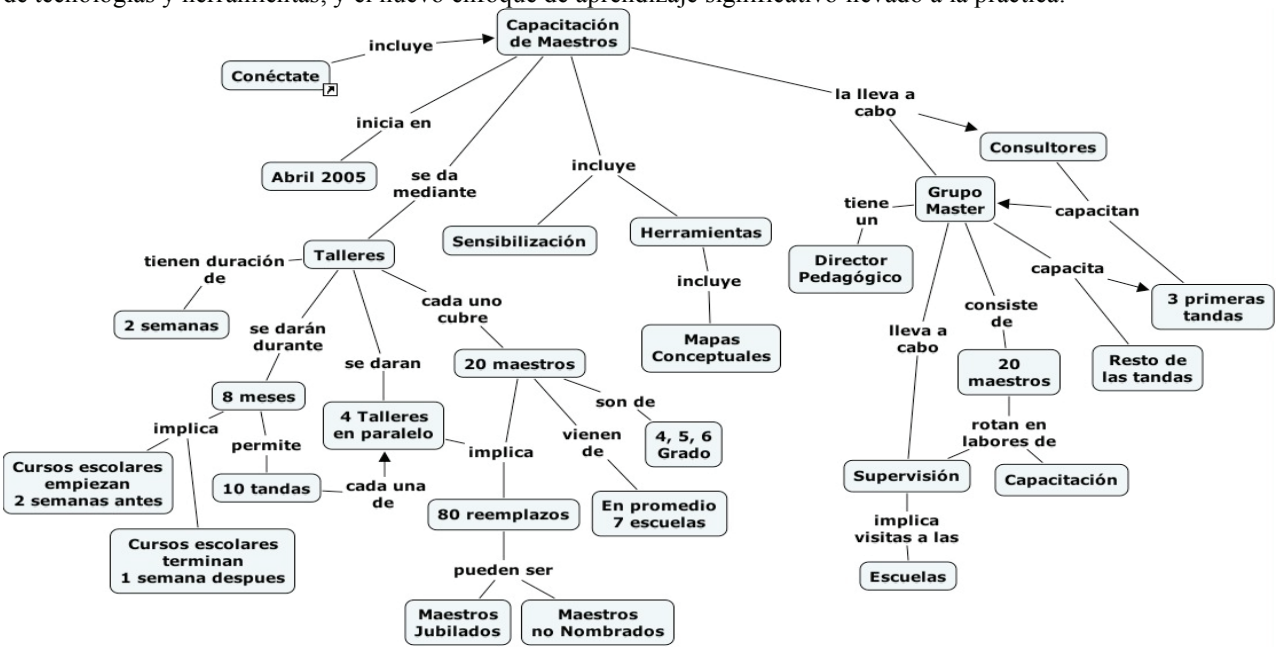


Figura 2. Ejemplo de un Mapa de los talleres, realizado colectivamente por facilitadores.

2.3 Aula de innovación y Red Nacional

El esfuerzo principal del proyecto se ha dirigido a identificar las escuelas que serán beneficiarias del proyecto en las diferentes etapas. Para el efecto se realizó una selección inicial de escuelas con condiciones de infraestructura apropiadas para establecer un Aula de innovación, y que representaran diferentes zonas geográficas y diferentes niveles de población.

El proceso busca que sean las escuelas las que manifiesten su interés, por ello, las siguientes etapas deben contar con expresiones directas de las autoridades, docentes y niños para participar. Más adelante, la selección se espera que surja de la presentación por parte de la escuela, de iniciativas y propuestas, con los cuáles espera beneficiarse del proyecto. La importancia de este aspecto, es que difiere de experiencias anteriores donde la participación es decidida por las autoridades centrales, en general sin contar con el interés o el compromiso de la escuela y de su comunidad.

Para finales del presente año, se tendrán instaladas Aulas de Innovación en cerca de 200 escuelas, lo cuál representa aproximadamente 4,000 computadoras que pronto estarán en Red. El Aula de Innovación se establece en un área específica de la escuela, y se incluyen, en promedio equipos para atender el grupo de mayor tamaño en la escuela. En general con 20 computadoras conectadas en red de área local y con salida a Internet. (Éste último aspecto será acelerado en próximos meses). El proyecto configurará más adelante la infraestructura técnica de la red para enlazar todas las escuelas y para contar con los servidores que habilitan la colaboración y la publicación de mapas de todos los niños, grados y grupos.

El proyecto, en éste aspecto, atrae la atención de organizaciones externas importantes. Recientemente, se suscribió un convenio de colaboración con la Empresa Cable and Wireless, mediante el cuál se establece el *Fondo para la Igualdad y la Alfabetización Digital*, promoviendo la elevación de la conectividad y fortaleciendo el desarrollo de la Red Nacional que propulsa Conéctate.

3 Implantación y Observaciones

3.1 Arquitectura institucional

El proyecto inició con apoyo del sector privado y a través de tres bancos financió los estudios y la consultoría de diseño. La Secretaría de la Presidencia de la República para la Innovación Gubernamental asume el liderazgo de la iniciativa, con apoyo de la Comisión Presidencial de Educación, que cuenta con la participación del Secretario Nacional de Ciencia y Tecnología, del Ministro de Educación y de la Directora de la Fundación Gabriel Lewis Galindo. Se creó una estructura operativa, con la cooperación del Programa de las Naciones Unidas para el Desarrollo – PNUD. La aportación del Gobierno Nacional, promedia unos 15 millones de dólares anuales, un reflejo explícito del compromiso prioritario con el logro de ésta meta.

Una decisión importante fue la de crear el proyecto por fuera de la estructura del Ministerio de Educación. Este acuerdo garantiza dos factores clave: la flexibilidad y la sostenibilidad. Para formalizarlo, el Gobierno presentó ante la Asamblea Legislativa la propuesta para crear el Patronato Panamá Aprende, como organismo autónomo, la cuál se aprobó. Su operación, integrado por personalidades del país, y se propone mantener la sostenibilidad al futuro.

La Unidad Operativa de Conéctate, cuenta con una dirección ejecutiva y coordinación en las áreas pedagógica, académica, tecnológica y administrativa. Se ha buscado que la organización sea flexible, comprometida y consistente con el enfoque constructivista del proyecto. La estructura orgánica debe ser dinámica, abierta y de amplia comunicación, para permitir y alentar la innovación. En ello se advierten dificultades, que requieren atención deliberada. Este grupo debe velar para que el proyecto no sea absorbido por el sistema que trata de cambiar.

3.2 Formación y Acompañamiento

Dentro del plan de implantación en las escuelas se ha observado la importancia que tuvo la definición inicial del proceso de formación, el cuál establece que el mismo continúa en la escuela cuando los maestros regresan de los talleres formales de capacitación. Esto definió un proceso de acompañamiento.

El proceso de acompañamiento reviste, entonces una importancia alta. Todo el equipo del proyecto se ha comprometido en establecer los elementos importantes que lo integran, y están confrontándolos con la realidad en las escuelas que tienen alta diversidad.

El seguimiento contiene importantes ingredientes de asesoría en sitio para elevar el dominio de los maestros sobre herramientas, conceptos y prácticas, observación de los fenómenos en la escuela, avances y problemas en la ejecución del proyecto, configuración de un registro y memoria sobre la trayectoria seguida por la escuela en el proceso. Una fase futura contempla el seguimiento en línea a través de la red nacional.

3.3 Colaboración

Este es un aspecto clave del diseño e implantación del proyecto. No se trata simplemente de una colección de escuelas conectadas a Internet. Se trata del montaje de una infraestructura deliberada para la colaboración, a partir de herramientas explícitamente diseñadas para eso. La visión del proyecto concibe ésta estructura como un solo sistema, dirigido a configurar un ambiente que propicia la colaboración, que facilita la asociación integral de maestros, niños, autoridades y escuelas, como un todo. Es un espacio común que excede los límites de la escuela.

Para ello se han hecho previsiones que habiliten formas nuevas de trabajar, que permitan a los niños conectarse no solo en la escuela sino desde su casa o lugares públicos, desde un espacio propio, con identidad única, y con herramientas poderosas y fáciles de usar, participar en construcciones colectivas de conocimiento, colaborando y aprendiendo a aceptar la crítica, reformulando y haciendo público su aprendizaje. El alcance previsto va mas allá de aprendizaje significativo y herramientas, es un entorno innovador que no tiene antecedentes en la vida escolar.

Conéctate es esencialmente una red humana, no solamente tecnológica, y desde ahí es coherente con los conceptos metodológicos que se impulsan: *La construcción de un mapa implica la integración de nodos –conceptos- por medio de enlaces que hacen que la relación entre ellos sea significativa y por lo tanto se conviertan en la*

esencia del cambio de la estructura cognitiva. La colaboración es un proceso esencial en el desarrollo de las habilidades para un mundo altamente interconectado en la construcción de conocimiento.

Para los niños panameños de las primarias participantes, la posibilidad de representar conocimiento y construirlo en forma colaborativa, es una verdadera innovación, particularmente en las escuelas más alejadas, donde casi nunca es posible incorporar estos avances en su estrategia normal. Un ejemplo del proceso que ya acontece, luce así:

- El maestro en clase orienta al niño o grupo de niños para que formulen una pregunta detonadora dentro del contexto de un proyecto sobre un tema significativo para ellos, que estimule su interés por expresar lo que saben del tema, y explorar a través de otros compañeros y de la Red Conéctate, respuestas a la pregunta.
- Con las herramientas, los niños colocan conceptos iniciales y algunos otros que les parezcan importantes.
- Trazan, enseguida, enlaces entre ellos para definir de forma clara y explícita qué relación existe. La representación de conceptos y relaciones configura un mapa.
- Pueden invitar a niños de otros grados o escuelas para que les hagan comentarios, críticas o aportes.
- A cada concepto pueden asociarle fácilmente, ilustraciones, incluyendo documentos, presentaciones, tablas, imágenes y videos.
- Pronto aprenden a enlazar otros mapas, propios y de compañeros, o mapas de profesionales y científicos. Estas colecciones de mapas pueden llegar a ser una estructura de conocimiento sobre un dominio particular, conectando el conocimiento de estudiantes en diferentes partes del país.
- Adquieren así, habilidades permanentes para imaginar, preguntar, reflexionar, explorar, sintetizar, construir, representar, compartir, negociar y hacer público su conocimiento.
- Maestros y niños de las escuelas, conectados entre sí crean una comunidad de aprendizaje, sin fronteras

Los progresos en el manejo de las herramientas, han facultado a los niños para establecer notables procesos de colaboración sobre elementos de conocimiento. Las propuestas de expresar conocimiento a través de mapas se captan con rapidez, atender las preguntas de enfoque y procurar un esquema participativo en la construcción y puesta en público ha sido resultante de un proceso de maduración que refleja el carácter de la innovación.

Un ejemplo interesante se presenta cuando durante una capacitación, un grupo de maestros trabajó sobre el tema de Marte. El Director, en la NASA, del Centro de Exploración del Planeta Marte, encontró los trabajos interesantes y entró en contacto directo con ellos. Es un proceso que difícilmente se presentaría, sin herramientas poderosas como CmapTools, conceptos de aprendizaje significativo y una visión orientada a la colaboración.

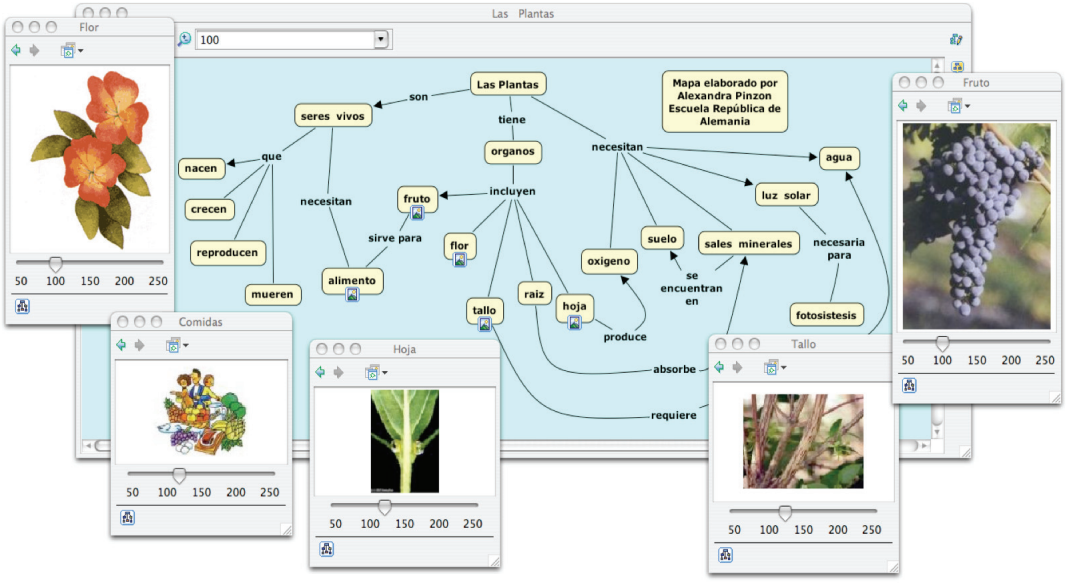


Figura 3. Mapa conceptual con imágenes enlazadas construido por niños panameños.

3.4 Observaciones preliminares

Se ha puesto atención al delicado problema de no dejar que la curva de aprendizaje del proyecto se estabilice en un nivel bajo, lo cuál acontece cuando al enfrentar dificultades en la gestión en la orientación académica o en la implantación, se concede reducir un poco la calidad a favor de lograr metas de tiempo o cuantitativas, y particularmente en la formación y desarrollo de la capacidad de los recursos humanos de proyecto.

Otro de los aspectos clave ha sido el de establecer un balance, difícil de lograr, entre la calidad de los procesos y el número de escuelas que es posible atender en un período determinado. El proyecto resolvió ajustar el compromiso con número de escuelas, a favor de realizar cuidadosamente los procesos de formación y de preparación. Desde el punto de vista de la ejecución, es importante la consideración de una conducta general del proyecto para dar atención a las solicitudes de ayuda, para no deteriorar el entusiasmo inicial en las contrapartes de las escuelas. Ello va dirigido también a crear comunidad, interacción entre las escuelas, que se sientan parte de todo el plan.

Se observa una amplia variedad en los resultados de los estudiantes, desde trabajos realizados con magnifico nivel y complejidad, hasta trabajos de una vez por mes o por semana, o tomar el trabajo con mapas como un punto del currículo, tratarlo y dejarlo.

Como complemento y resultado de su trabajo de capacitación, seguimiento, apoyo y desarrollo de material, los facilitadotes realizan proyectos de investigación. Algunos ya han arrojado resultados interesantes que se presentan en este congreso: el desarrollo de una taxonomía topológica de mapas conceptuales, (Cañas et al., 2006), un juego con dados para aprender a generar proposiciones, (Hughes et al., 2006), un estudio sobre las preconcepciones de los maestros panameños sobre los mapas conceptuales, (Miller et al., 2006), un caso de estudio del éxito de una maestra panameña en la implementación de la metodología en el aula, (Rodríguez et al., 2006), una evaluación del impacto de introducir a los maestros al uso de CmapTools sin una previa alfabetización computacional, (Suárez et al., 2006), la influencia del estilo de pensamiento en el desarrollo de los mapas conceptuales (Chacón et al., 2006) y un experimento del efecto de la primera impresión en la evaluación de mapas conceptuales (Carvajal et al., 2006).

Conéctate al Conocimiento, es un proyecto que pone en las manos de los niños de las escuelas públicas, las más poderosas herramientas para construcción, representación y publicación de conocimiento hasta hoy inventadas. Es la resultante de los esfuerzos de un equipo prodigioso de personas, animadas por una sola fuerza: El futuro de la niñez.



Figura 4.Dr. Novak (Izq), el Presidente de la República y el Secretario de la Presidencia para la Innovación Gubernamental dando Seguimiento a los trabajos de aula en las escuelas

Finalmente, podría afirmarse que con las herramientas de este proyecto, se reduce a cero la distancia entre los niños de las escuelas de Panamá y los más importantes centros científicos del mundo que las usan.

Referencias

Ausubel, D.P., Novak, J. D., (1978). Educational Psychology: A cognitive view. New York. Holt Rinehart & Winston.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cañas, A. J., Novak, J. D., Miller, N. L., Collado, C., Rodríguez, M., Concepción, M., Santana, C., Peña, L. (2006) Confiabilidad de una Taxonomía Topológica para Mapas Conceptuales. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Carvajal, R., Cañas, A. J., Carballeda, M., Hurtado, J. (2006). Assessing Concept Maps: First Impressions Count.En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Chacón, L. (2006). Influencia del Estilo de Pensamiento en la Construcción de Mapas Conceptuales. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Hughes, G., Barrios, J. del C., Bernal, D.,, Chang, A., Cañas, A. J. (2006) Los Dados Conceptuales: Un Juego para Aprender a Construir Proposiciones. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Miller, N. L, Cañas, A. J., Novak, J. D. (2006) Preconceptions Regarding Concept Maps Held by Panamanian Teachers. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Rodríguez, M. A., Coloma, E. (2006). Mapas Conceptuales en las Aulas Panameñas: Aptitud para Cambiar Actitud. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Suarez, L., Villareal Bermúdez, K. (2006). ¿Hace Falta la Alfabetización Computacional Antes de la Inmersión de los Maestros a la Tecnología en la Escuela? Una Respuesta usando CmapTools. En: En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

[1] World Economic Forum WEF www.weforum.org – incluye el nuevo índice de conectividad (NRI).

[2] OECD PISA . Evalúa las habilidades de pensamiento en los estudiantes de los países miembros para áreas como Lectura, matemáticas y ciencias, y los compara con otros países a nivel Mundial. www.pisa.oecd.org.

[3] WSIS – Intervención de Secretario General de las Naciones Unidas, Kofi Anan durante la Inauguración de la Cumbre Mundial de la Sociedad de Información , Túnez Noviembre de 2005. http://www.itu.int/wsis/.

[4] Papert, S., Una critica al tecnocentrismo www.papert.com.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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CONFIABILIDAD DE UNA TAXONOMÍA TOPOLÓGICA PARA MAPAS CONCEPTUALES

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Resumen. Llegar a construir mapas conceptuales de calidad, que muestren claramente comprensión y entendimiento del tema representado es un proceso que usualmente empieza con mapas pobres, tanto en su estructura topológica como en su semántica, y que mejora con el tiempo, práctica y retroalimentación de parte del maestro o personas con mayor experiencia. En el Proyecto Conéctate al Conocimiento en Panamá, donde se está llevando una introducción a gran escala del uso de mapas conceptuales en las escuelas públicas primarias mediante capacitación y apoyo a maestros de aula, se hace imprescindible tener un instrumento que permita medir el progreso en el desarrollo de mapas 'a grosso modo' a nivel de aulas y escuelas. En contraste con esquemas de evaluación de mapas conceptuales que tienen como objetivo calificar los mapas, hemos desarrollado una taxonomía de mapas conceptuales, análoga a la taxonomía de Bloom, que permite a personal del Proyecto tener un termómetro del avance en el aprovechamiento de los mapas conceptuales como herramienta de aprendizaje significativo. La taxonomía consiste de dos partes, una taxonomía topológica y una taxonomía semántica. En este artículo presentamos la taxonomía topológica y un estudio de confiabilidad de su aplicación por parte del personal pedagógico del Proyecto. Los resultados de este estudio nos dan motivos para pensar que, con un poco de práctica, esta herramienta resultará sumamente útil y confiable.

1 Introducción

En el 2005 se puso en marcha en Panamá el Proyecto *Conéctate al Conocimiento* (Tarté, 2006), un proyecto de transformación de la Educación Panameña que adelanta el Gobierno Nacional a través de la Secretaría de la Presidencia para la Innovación Gubernamental y del Ministerio de Educación. Dicho proyecto contempla, entre otras cosas, la capacitación de docentes de escuelas primarias oficiales en el uso de mapas conceptuales como herramienta para fomentar el aprendizaje significativo en sus estudiantes; incluye también visitas de apoyo a las escuelas para brindar a los docentes la ayuda necesaria para mejorar la calidad del aprendizaje.

Los reportes, tanto verbales como escritos, que resultaron de las primeras visitas de seguimiento, se caracterizaban por su alto grado de subjetividad. Los facilitadores — responsables de la capacitación y seguimiento — regresaban de las visitas describiendo los mapas conceptuales de los niños con diversos adjetivos calificativos y, por supuesto, cada uno utilizaba sus propios criterios a la hora de asignarle estos calificativos. Los informes también reportaban una amplia gama de mapas conceptuales, desde mapas de alta calidad que mostraban un profundo nivel de entendimiento por parte de los estudiantes, hasta mapas con trozos de texto y con estructuras básicamente lineales. Sin embargo, la falta de un 'lenguaje común' con qué describir la variedad de mapas impedía determinar objetivamente los avances logrados por los diferentes maestros en el desarrollo de su trabajo con los mapas conceptuales y tomar decisiones sobre el nivel de apoyo que las diferentes escuelas requerían. De aquí nace la necesidad de desarrollar una taxonomía de mapas conceptuales. Hemos dividido la taxonomía en dos: una taxonomía topológica y una taxonomía semántica. La taxonomía topológica considera la complejidad estructural del mapa, sin dar importancia al significado de conceptos y proposiciones, y se presta para medir el progreso en los inicios, cuando el estudiante está aprendiendo los aspectos elementales en la construcción del mapa, por ejemplo, conceptos formados por una o pocas palabras, proposiciones, y enlaces cruzados. La taxonomía semántica, aún en fase de desarrollo, considera la calidad del contenido del mapa, por ejemplo, la relevancia de las proposiciones y la calidad de conceptos y enlaces. En este artículo describimos el proceso de validación de la taxonomía topológica.

Queremos destacar que esta taxonomía no ha sido concebida como una herramienta de calificación de mapas conceptuales. Sus características responden a una necesidad puntual del Proyecto Conéctate. Tampoco es nuestra intención que la misma sea utilizada por los docentes para evaluar a sus estudiantes, pues lo que menos desearíamos sería dar la impresión de que existe una forma "correcta" de evaluar mapas conceptuales. La taxonomía fue desarrollada para servir de apoyo en la consecución de objetivos concretos del Proyecto y como instrumento de investigación. Desde esta perspectiva, la herramienta sería aplicada por una población de evaluadores limitada, a saber, los facilitadores del Proyecto Conéctate, quienes comparten un entendimiento común sobre mapas conceptuales.

2 Taxonomía de Mapas Conceptuales

En el Proyecto Conéctate se tenía la necesidad de una taxonomía de mapas conceptuales, análoga a la taxonomía de Bloom (1956). Bloom, junto con un grupo de investigadores, desarrolló una clasificación de niveles de comportamiento intelectual importantes para el aprendizaje. En el dominio cognitivo identificó seis niveles, desde el simple reconocimiento y memorización de datos e información en el nivel más bajo, pasando por niveles mentales más complejos y abstractos, hasta el nivel más alto que es la evaluación o apreciación en base a criterios específicos. La taxonomía de Bloom provee un instrumento útil con el cual categorizar el nivel de abstracción de preguntas de exámenes. La taxonomía de mapas conceptuales, por su parte, debería proveer un mecanismo para determinar el nivel de progreso en la representación de los mapas conceptuales, partiendo de mapas sencillos, con secuencias de conceptos y textos en los nodos y sin frases de enlace, hasta mapas con proposiciones claras, buenos enlaces cruzados, recursos relevantes enlazados, y enlaces a otros mapas.

En la literatura existen numerosos esquemas de evaluación o rúbricas para evaluar el contenido de mapas conceptuales. Un esquema que ha tenido bastante divulgación fue el propuesto por Novak & Gowin (1984), y que evalúa tanto componentes semánticos como estructurales. En este esquema evaluativo se toman en cuenta proposiciones válidas, niveles de jerarquía, ramificaciones, enlaces cruzados y ejemplos. La idea, como explican Coffey et al. (2003), es que los niveles jerárquicos son reflejo del grado de subsunción entre conceptos, las ramificaciones revelan la diferenciación progresiva, mientras que los enlaces cruzados ponen de manifiesto el grado de integración del conocimiento. Sin embargo, no se trata de una taxonomía, sino de una forma de evaluación o calificación de mapas conceptuales.

Por el contrario, son pocos los esquemas propuestos para evaluar únicamente la estructura topológica de mapas conceptuales. Kinchin (2000) propuso una clasificación que incluía 3 topologías: radial, de cadena y de red. De las tres, señala que la estructura de red es la más compleja e indicativa de un aprendizaje significativo. Más recientemente, Yin et al. (2004), dentro del marco de un estudio de comparación de dos técnicas de construcción de mapas conceptuales, examinan también la complejidad estructural de los mapas. Aunque inicialmente se basan en la taxonomía de Kinchin, encuentran que esta clasificación no les permite caracterizar la totalidad de las estructuras observadas en su estudio, por lo que añaden 2 más. Su esquema consiste entonces de las siguientes topologías, ordenadas de lo más simple a lo más complejo: lineal, circular, radial, de árbol, y de red. De nuevo, ninguno de estos estudios provee una taxonomía con diferentes niveles que muestre el progreso en la construcción de mapas.

Nuestra experiencia observando el trabajo inicial con mapas conceptuales por parte de estudiantes en las escuelas, y nuestro conocimiento de las preconcepciones de los maestros panameños sobre mapas conceptuales (Miller, Cañas, & Novak, 2006), nos indicaban que la necesidad inicial era de una taxonomía principalmente topológica. Por un lado, al aprender a construir mapas conceptuales es común introducir textos largos en los conceptos, crear hileras largas de conceptos, ignorar las frases de enlace, y no introducir enlaces cruzados. Por otro lado, como ponían en evidencia los reportes de visitas de los facilitadores, al retornar a sus escuelas algunos docentes volvían a las estructuras de mapas que conocían y manejaban antes de recibir la capacitación: estructuras que tendían a ser esencialmente lineales y en las que no tenían cabida los enlaces cruzados.

La taxonomía que presentamos en este artículo es, pues, una taxonomía fundamentalmente topológica, y surge de la necesidad de tener una forma más objetiva y confiable de medir nuestros logros hacia la meta específica de avanzar hacia formas de representación de conocimiento que verdaderamente permitan a su autor reflejar la complejidad de su pensamiento. Esta taxonomía topológica es complementada por una taxonomía semántica, que permite valorar la complejidad de los mapas conceptuales basándose primordialmente en la calidad de su contenido. En el resto de este artículo presentamos la taxonomía topológica, y un estudio de validación de la misma realizado con facilitadores del Proyecto Conéctate.

3 La taxonomía topológica

La taxonomía topológica desarrollada por nuestro equipo de trabajo (ver apéndice) tiene por objeto medir la complejidad estructural de los mapas conceptuales en el contexto específico del Proyecto Conéctate. Aunque guarda ciertas semejanzas con las clasificaciones descritas en la sección anterior, particularmente la de Yin et al., es más amplia y detallada que ésta, y es producto de nuestra experiencia con mapas conceptuales elaborados por maestros y

estudiantes panameños. Está supuesta a ser de fácil y rápida implementación, y lo suficientemente sencilla que su aplicación permita ir desarrollando en el evaluador la habilidad de reconocer prácticamente a simple vista el nivel topológico de un mapa. La topología consta de 7 niveles (del 0 al 6), en los cuales se valoran cinco criterios: a) el uso de conceptos en vez de trozos de texto, b) el establecimiento de relaciones entre conceptos, c) el grado de ramificación, d) la profundidad jerárquica, y e) la presencia de enlaces cruzados.

Evidentemente el primer criterio, es de carácter semántico más que estructural. Lo hemos incluido porque, en nuestro medio, la presencia de trozos de texto en un mapa conceptual suele ser indicativa de estructuras de conocimiento memorísticas, y por ende pobres, rígidas y aisladas. Pensamos que, por el contrario, la capacidad de desglosar textos en conceptos es el punto de partida obligado para el establecimiento de relaciones múltiples, novedosas y flexibles entre ideas y, por ende, para la construcción de estructuras cognitivas cada vez más complejas y sofisticadas. Tanta importancia le otorgamos a esto, que un mapa en el que predominan trozos de texto recibe en nuestra taxonomía la valoración más baja (0), independientemente de su complejidad o de la presencia de cualquier otro elemento estructural.

El segundo criterio tiene, sin lugar a dudas un componente semántico. Sin embargo, para efectos de esta taxonomía, se considera únicamente su dimensión estructural. Es decir, lo que interesa es la presencia o no de palabras de enlace, no las palabras en sí. Desde esta óptica, cualquier símbolo colocado intencionalmente por el autor con el fin de establecer una relación concreta entre dos conceptos debe ser interpretado como "palabra de enlace". Esta consigna aplica igualmente a mapas conceptuales elaborados a mano (con papel y lápiz, u otros materiales), como a los realizados mediante un programa de computadora. Algunos programas, por ejemplo CmapTools (Cañas et al., 2004), colocan automáticamente un recuadro con signos de interrogación para la frase de enlace cuando el autor une un concepto con otro. Esto no puede interpretarse como palabra de enlace.

La ramificación de un mapa conceptual está asociada al número de puntos de ramificación. Un *punto de ramificación* ocurre cuando de un nodo, concepto o frase de enlace, salen 2 o más líneas de conexión (el número exacto no importa). Conviene hacer hincapié en que este criterio no se refiere al número de ramas que emergen de un nodo dado, sino al número de nodos que presentan más de una rama.

La *profundidad jerárquica* de un mapa se determina contando el número de enlaces que hay entre el concepto raíz[1] y el concepto más alejado del concepto raíz. Evidentemente este es un criterio que sólo tiene sentido para mapas que contienen al menos un concepto raíz. En el contexto del Proyecto Conéctate, sin embargo, esto no es realmente una limitante, ya que en los talleres del proyecto se enseña que todo mapa conceptual debe responder a una *pregunta de enfoque*, y esto usualmente conlleva a que la elaboración del mapa inicie a partir de un concepto raíz, independientemente de la forma que posteriormente pueda adoptar el mapa.

El último criterio evalúa la presencia de enlaces cruzados. Un *enlace cruzado* es esencialmente una proposición entre conceptos ninguno de los cuales es el concepto raíz, y usualmente localizados en diferentes sectores de un mapa conceptual, de manera tal que se forme un circuito cerrado.

4 Validación de la Taxonomía: Materiales y métodos

El objetivo de la taxonomía desarrollada es tener un lenguaje común mediante el cual los facilitadores puedan determinar el avance en la calidad de los mapas conceptuales desarrollados por los estudiantes en el Proyecto Conéctate con el objetivo de tomar decisiones. Es crítico, por tanto, determinar la consistencia que puede esperarse en la aplicación de esta taxonomía por parte de los facilitadores. En esta sección presentamos el proceso de validación de la taxonomía topológica.

4.1 Selección de la muestra

A fin de intentar garantizar que la muestra constituida tuviese igual posibilidad de incluir mapas conceptuales de cada uno de los 7 niveles topológicos, un grupo de facilitadores seleccionó de entre los mapas creados por los docentes durante los talleres de capacitación, los realizados por niños en las escuelas participantes y recogidos

[1] El *concepto raíz* es el concepto más abarcador, del cual se desprenden el resto de los conceptos del mapa.

durante las visitas de apoyo, y otros disponibles en los servidores públicos de la red de CmapTools, un total de 210 mapas conceptuales, 30 de cada nivel. Éstos se mezclaron para conformar un universo a partir del cual se obtuvo una muestra aleatoria de 50 mapas conceptuales. Antes de proceder a trabajar con la muestra, se revisó cada uno de los mapas para cubrir marcas de identificación u otras marcas ajenas al mapa conceptual original[2].

Cabe destacar que 24 de los 50 mapas conceptuales de la muestra fueron hechos a mano y los 26 restantes con algún programa de computadora. También hacemos notar que 8 están en un idioma que no es Español y que 5 no presentan la forma clásica de un mapa jerárquico, con el concepto raíz en la parte superior del mapa y los conceptos más específicos debajo de éste.

4.2 Protocolo experimental

El estudio se realizó en dos fases: una primera fase preliminar, para terminar de depurar la taxonomía, y una segunda fase, cuyos resultados son los que se reportan en este estudio de confiabilidad. En la primera fase participaron 16 evaluadores. Ninguno de estos evaluadores tuvo experiencia alguna con la taxonomía topológica previa al estudio. Los evaluadores evaluaron la muestra de 50 mapas de forma individual. A cada mapa debía asignársele un nivel topológico de acuerdo con la taxonomía topológica.

Antes de dar inicio a la segunda fase, se realizó una sesión de capacitación en la que se hizo una presentación formal de la herramienta, así como una pequeña práctica con 6 mapas conceptuales para aclarar dudas. Luego se procedió con la segunda fase. Participaron los 26 facilitadores del Proyecto disponibles, con excepción de aquellos que fueron partícipes del diseño del instrumento.

A fin de garantizar una evaluación completamente independiente por parte de los facilitadores, éstos se repartieron entre varios salones y la evaluación de los mapas se llevó a cabo en una sesión única. Los evaluadores estuvieron acompañados en todo momento por al menos un miembro del equipo de investigación. A cada evaluador se le entregaron dos documentos: 1) la *taxonomía topológica, y 2)* las *instrucciones de uso de la taxonomía topológica*.

4.3 Características de los evaluadores

Todos los evaluadores que participaron en este estudio están vinculados al Proyecto Conéctate al Conocimiento. De acuerdo a su antigüedad en el Proyecto, están distribuidos de la siguiente manera: 10 pertenecen al primer grupo de facilitadores, reclutados y entrenados en Febrero del 2005; 3 provienen del segundo grupo, reclutados y entrenados en Julio del 2005; y 13 provienen del último grupo, reclutados y capacitados en Diciembre del 2005. Al momento de realizarse este estudio, los facilitadores del primer, segundo y tercer grupo habían dictado, respectivamente, 18, 12 y 5 talleres de capacitación a maestros, de dos semanas tiempo completo cada uno. Desde el punto de vista de formación profesional, el grupo de evaluadores es sumamente diverso. Incluye, entre otros profesionales, a físicos, psicólogos, educadores, publicistas, biólogos, y agrónomos. El 58% de los evaluadores son mujeres.

4.4 Medidas de concordancia

El grado de acuerdo entre evaluadores se determinó mediante dos estadísticas de concordancia: el *porcentaje de acuerdo observado* y el *coeficiente kappa*, no ponderado (o simple) y ponderado[3]. El coeficiente *kappa* mide el grado de consenso entre observadores más allá del que pueda darse meramente por el azar (Abraira, 1997). Tanto para el sondeo preliminar como para la validación final, el número de evaluadores era mayor que 2 (16 y 26, respectivamente); por tanto, para obtener las estadísticas de concordancia para cada grupo de evaluadores, éstas se calcularon primero para todos los posibles pares de evaluadores de ese grupo[4]. Luego se obtuvo la media de los pares y se construyeron intervalos de confianza para la media. Para la interpretación de los valores de *kappa* se ha

[2] En el caso de mapas recogidos en las escuelas, por ejemplo, algunos mapas presentaban comentarios y/o correcciones de los maestros.

[3] Se optó por una ponderación lineal, calculada mediante la fórmula $1-\left|\frac{i-j}{k-1}\right|$, donde *k* es el número total de categorías; un peso de 1 significa que la distancia entre categorías asignadas por ambos evaluadores es la mínima posible, es decir, no hay desacuerdo; un peso de 0 significa que la distancia entre categorías es la máxima posible, en este caso, 6.

[4] Para los cálculos estadísticos se utilizó principalmente el programa STATA, versión 9; algunos cálculos se realizaron con Excel.

utilizado la escala que aparece en la tabla 1, propuesta por Landis & Koch (1977) y ampliamente empleada en la literatura de estudios de confiabilidad.

Coeficiente *kappa*	Grado de acuerdo
< 0	No hay acuerdo (salvo por azar)
0 – 0.2	Insignificante
0.21 – 0.4	Bajo
0.41 – 0.6	Moderado
0.61 – 0.8	Bueno
0.81 - 1	Muy bueno

Tabla 1. Interpretación del valor del coeficiente *kappa*

5 Resultados

Los resultados y observaciones de la fase preliminar, así como los comentarios de los evaluadores participantes, pusieron en evidencia la necesidad de realizar algunas modificaciones a la taxonomía y a las instrucciones para su aplicación, antes de proceder con la segunda fase. Las principales modificaciones fueron: 1) clarificar la descripción del criterio relacionado con grado de ramificación; 2) clarificar cómo utilizar la taxonomía, particularmente cuando un mapa no cumple con todas las condiciones de un nivel dado; 3) hacer mayor énfasis en que el objetivo de la herramienta es evaluar la estructura de un mapa conceptual y no su contenido; 4) reducir el tamaño de la muestra, para evitar el factor cansancio[5]; 5) excluir de la muestra todos los mapas en un idioma distinto al Español[6], así como aquellos en los que el concepto raíz no esté en la parte superior del mapa[7]. La muestra utilizada para la validación final, es una sub-muestra de la muestra original, y estuvo compuesta de un total de 30 mapas conceptuales.

El análisis de los datos indica que el porcentaje de acuerdo fue del 55.7%, con un intervalo de confianza del 95% de (54.5%, 57.0%)[8]. El coeficiente *kappa* simple fue de 0.4778, IC95% = (0.4627, 4930), lo que corresponde a un acuerdo *moderado*, mientras que el coeficiente kappa con ponderación lineal fue de 0.7215, IC95% = (0.7106, 0.7324), equivalente a un acuerdo *bueno*.

Con el fin de intentar explicar las discrepancias que se dieron entre los evaluadores, se procedió a revisar la distribución de las evaluaciones por mapa conceptual. De los 30 mapas, 8 presentaban un grado de variabilidad importante en su evaluación. Consideramos que un mapa conceptual presenta "variabilidad importante" si la distribución de las evaluaciones abarca 4 o más niveles, independientemente de si muestra una clara preferencia por algún nivel o no.

[5] En la fase preliminar, el nivel de acuerdo en la primera mitad de la muestra fue significativamente mayor al nivel de acuerdo en la segunda mitad. Dado el tamaño de la muestra, sospechamos que el cansancio pudo ser la causa principal de esta diferencia. Esta sospecha fue corroborada por algunos evaluadores quienes manifestaron "haberse sentido bastante cansados después de los primeros 25-30 mapas" y "no haberse apegado tan estrictamente a la taxonomía después de la primera mitad."

[6] Los resultados, corroborados por comentarios de los evaluadores, indican que esto hizo más difícil distinguir entre conceptos largos y trozos de texto.

[7] Los evaluadores señalaron que les costó más trabajo clasificar aquellos mapas conceptuales que tenían el concepto raíz en el centro o cerca del centro. Esto pudo deberse a que este tipo de estructura les es mucho menos familiar (los mapas que se enseñan y construyen en el Taller de Conéctate típicamente tienen el concepto raíz en la parte superior) , lo que a su vez pudo haber dificultado la valoración de aspectos como la ramificación y la profundidad jerárquica.

[8] En adelante utilizaremos la abreviación *IC95%* para referirnos a este intervalo.

Un examen concienzudo de estos 8 mapas conceptuales revela que las diferencias parecen deberse a que los evaluadores no contaron correctamente alguna variable y/o no se ciñeron rigurosamente a las instrucciones de la taxonomía (ver tabla 2). En ningún caso encontramos elemento alguno de la taxonomía o sus instrucciones que pudiese explicar las discrepancias en la evaluación de alguno de estos mapas.

Número del mapa	Observaciones
4	Había que contar con cuidado el número de enlaces que faltaban.
10	Había que contar con cuidado el número de enlaces cruzados.
11	Había que contar con cuidado el número de enlaces cruzados, al igual que los niveles de jerarquía.
14	Había que contar con cuidado el número de enlaces cruzados.
16	Había que darse cuenta que faltaba un enlace.
17	Ninguna observación particular.
24	Había que tener cuidado al contar los niveles de jerarquía.
27	Había que distinguir entre nombres propios largos y trozos de texto.

Tabla 2. Señas particulares de los 8 mapas conceptuales que presentaron una variación importante en su evaluación

Finalmente, se consideró la distribución de todos los posibles pares de evaluaciones (ver tabla 3), con el fin de detectar aquellos niveles entre los cuales hubo mayor discrepancia. Los más altos porcentajes de desacuerdo (en rojo) se observan entre los niveles 0 y 1 con 36.9% (5.5/14.9), entre 1 y 2 con 49.7% (9.9/19.9), entre 2 y 3 con 27.9% (6.0/21.5), entre 3 y 4 con 20.8% (2.6/12.5), entre 4 y 5 con 28.8% (3.4/11.8), y entre 5 y 6 con 64.4% (6.7/10.4). Como puede verse, las discrepancias más importantes son de apenas un nivel de diferencia.

	Nivel 0	Nivel 1	Nivel 2	Nivel 3	Nivel 4	Nivel 5	Nivel 6
Nivel 0	**7.1%**						
Nivel 1	**5.5%**	**9.5%**					
Nivel 2	2.1%	**9.9%**	**11.2%**				
Nivel 3	0.0%	0.4%	**6.0%**	**7.2%**			
Nivel 4	0.0%	0.2%	1.0%	**2.6%**	**7.7%**		
Nivel 5	0.1%	0.0%	2.2%	1.6%	**3.4%**	**3.7%**	
Nivel 6	0.1%	0.0%	1.1%	1.1%	0.7%	**6.7%**	**9.0%**
Sub-totales	**14.9%**	**19.9%**	**21.5%**	**12.5%**	**11.8%**	**10.4%**	**9.0%**

Tabla 3. Distribución de los 9750 posibles pares de evaluaciones de 30 mapas conceptuales por 26 evaluadores

6 Discusión

Los resultados de este estudio sugieren que la taxonomía topológica que hemos desarrollado tiene un nivel de confiabilidad de *moderada* a *buena*. Esta conclusión la apoyan tanto el porcentaje de acuerdo (55.7%), como el coeficiente *kappa* simple (0.4778) y con ponderación lineal (0.7215).

Cabe destacar que de los dos coeficientes *kappa*, consideramos que el ponderado es el más apropiado para una taxonomía de 7 niveles como la nuestra, ya que el coeficiente *kappa* simple penaliza demasiado aún la mínima diferencia entre evaluadores. El importante aumento en el valor de *kappa* al aplicar la ponderación lineal sugiere que las diferencias entre evaluadores, en general, no eran tan grandes. Esta apreciación la confirman los porcentajes de la tabla 2, en la que se ve claramente que las diferencias más grandes fueron de un solo nivel.

Aún así, el hecho de que haya un alto porcentaje de discrepancia entre prácticamente todos los niveles consecutivos podría ser indicativo de 2 cosas: 1) falta de claridad en la taxonomía (su definición o sus instrucciones), y 2) falta de práctica o rigurosidad de los facilitadores al aplicarla. En base al análisis de los 8 mapas

conceptuales que más variación presentaron en su clasificación, pensamos que la segunda explicación es la más probable, y que la confiabilidad de nuestra taxonomía topológica pudiera aumentar de manera considerable conforme aumenta la familiaridad y experiencia de los evaluadores con la herramienta.

Para fines del Proyecto Conéctate, sin embargo, los resultados obtenidos pueden considerarse satisfactorios, pues permitirán determinar con bastante certeza los logros del Proyecto en el aspecto estructural de los mapas, así como el nivel de apoyo que debe brindársele a determinada escuela o docente.

7 Conclusiones

En este artículo se presentó una taxonomía para clasificar la estructura de mapas conceptuales elaborados por maestros y estudiantes que participan del Proyecto Conéctate al Conocimiento, y se midió su confiabilidad. Los resultados muestran que la herramienta tiene un nivel de confiabilidad *moderado*, si requerimos acuerdo exacto, y *bueno* si se utiliza una métrica ponderada linealmente. En vista de que las discrepancias entre evaluadores parecen deberse principalmente a la falta de práctica y/o falta de rigurosidad en la aplicación de la herramienta, creemos que con la experiencia la taxonomía puede llegar a tener niveles de confiabilidad superiores a los observados en este estudio.

8 Agradecimientos

Nuestro agradecimiento a todos los facilitadores que participaron de este estudio. Gracias especiales a los facilitadores María Carballeda y José Eloy Hurtado, por su apoyo en la preparación del experimento, y al Profesor Néstor Arguea por su ayuda en el procesamiento de los datos.

9 Bibliografía

Abraira, V. J. (1997). Precisión de las Clasificaciones Clínicas [Electronic Version], Tesis Doctoral. Consultado Abril 10, 2006 de http://www.ucm.es/BUCM/tesis/19972000/X/3/X3044301.pdf.

Bloom, B. S. (1956). *Taxonomy of Educational Objectives; the Classification of Educational Goals* (1st ed.). New York: Longmans Green.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W., Carnot, M. J., Feltovich, P. J., Feltovich, J., Hoffman, R. R., Cañas, A. J., et al. (2003). A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support (Technical Report submitted to the US Navy Chief of Naval Education and Training). Pensacola, FL: Institute for Human and Machine Cognition.

Kinchin, I. M. (2000). Using Concept Maps To Reveal Understanding: A Two-Tier Analysis. School Science Review, 81(296), 41-46.

Landis, J. R. & Koch, G. G. (1977). The measure of observer agreement for categorical data. Biometrics, 33, 159-174.

Miller, N., Cañas, A. J., & Novak, J. D. (2006). Preconceptions Regarding Concept Maps held by Panamanian Teachers. In A. J. Cañas & J. D. Novak (Eds.), Concept Maps: Theory, Methodology, Technology. *Proceedings of the Second Int. Conf. on Concept Mapping*. San José, Costa Rica: Univ. de Costa Rica.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York, NY: Cambridge University Press.

Tarte, G. (2006). Conéctate al Conocimiento: Una Estrategia Nacional de Panamá basada en Mapas Conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Yin, Y., Vanides, J., Ruiz-Primo, M. A., Ayala, C. C., & Shavelson, R. (2004). A Comparison of Two Contract-a-Concept-Map Science Assessments: Created Linking Phrases and Selected Linking Phrases (No. CSE Report 624): Center for the Study of Evaluation, National Center for Research on Evaluation, Standards, and Student Testing.

Apéndice

TAXONOMÍA TOPOLÓGICA

Nivel 0

a) *Predominan explicaciones largas sobre conceptos*
b) *Sin palabras de enlace*
c) *Lineal (0-1 puntos de ramificación)*

Nivel 1

a) *Predominan conceptos sobre explicaciones largas*
b) *Faltan la mitad o más de las palabras de enlace*
c) *Lineal (0-1 puntos de ramificación)*

Nivel 2

a) *Predominan conceptos sobre explicaciones largas*
b) *Faltan menos de la mitad de las palabras de enlace*
c) *Ramificación baja (2 puntos de ramificación)*

Nivel 3

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación media (3-4 puntos de ramificación)*
d) *Menos de 3 niveles de jerarquía*

Nivel 4

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación alta (5-6 puntos de ramificación)*
d) *3 o más niveles de jerarquía*

Nivel 5

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación alta (5-6 puntos de ramificación)*
d) *3 o más niveles de jerarquía*
e) *De 1-2 enlaces cruzados*

Nivel 6

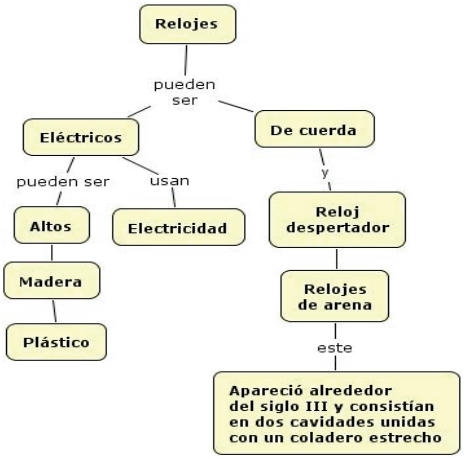
a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación muy alta (7 o más puntos de ramificación)*
d) *3 o más niveles de jerarquía*
e) *Más de 2 enlaces cruzados*

Al aplicar la taxonomía, el evaluador debe ceñirse a lo siguiente:

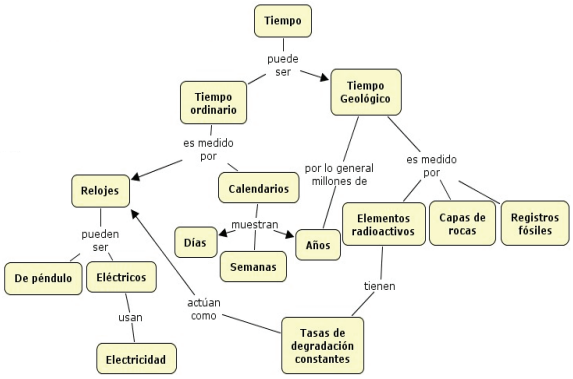
- Para pertenecer a un nivel dado, un mapa debe cumplir con **todos** los requisitos de ese nivel.
- Si un mapa no cumple con alguno de los requisitos de un nivel dado, entonces no pertenece a ese nivel sino a algún nivel más bajo.

Nota: Puede darse el caso de que un mapa de un nivel dado presente elementos de un nivel superior; sin embargo, sólo cuando presente **todos** los elementos de ese nivel superior podrá pertenecer a él.

Ejemplo de mapa conceptual de nivel 2



Ejemplo de mapa conceptual de nivel 5



Apéndice

TAXONOMÍA TOPOLÓGICA

Nivel 0

a) *Predominan explicaciones largas sobre conceptos*
b) *Sin palabras de enlace*
c) *Lineal (0-1 puntos de ramificación)*

Nivel 1

a) *Predominan conceptos sobre explicaciones largas*
b) *Faltan la mitad o más de las palabras de enlace*
c) *Lineal (0-1 puntos de ramificación)*

Nivel 2

a) *Predominan conceptos sobre explicaciones largas*
b) *Faltan menos de la mitad de las palabras de enlace*
c) *Ramificación baja (2 puntos de ramificación)*

Nivel 3

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación media (3-4 puntos de ramificación)*
d) *Menos de 3 niveles de jerarquía*

Nivel 4

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación alta (5-6 puntos de ramificación)*
d) *3 o más niveles de jerarquía*

Nivel 5

a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación alta (5-6 puntos de ramificación)*
d) *3 o más niveles de jerarquía*
e) *De 1-2 enlaces cruzados*

Nivel 6

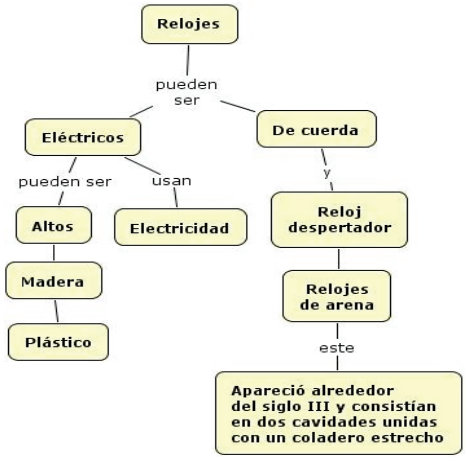
a) *Sin explicaciones largas*
b) *No faltan palabras de enlace*
c) *Ramificación muy alta (7 o más puntos de ramificación)*
d) *3 o más niveles de jerarquía*
e) *Más de 2 enlaces cruzados*

Al aplicar la taxonomía, el evaluador debe ceñirse a lo siguiente:

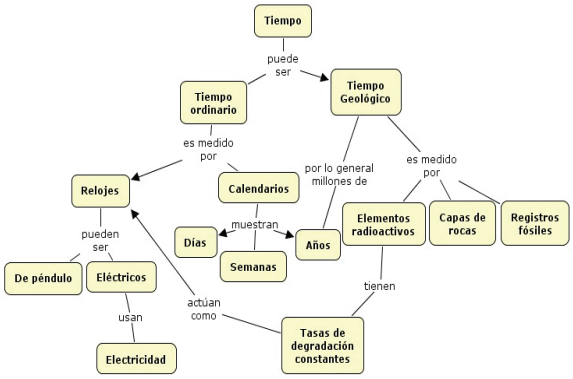
- Para pertenecer a un nivel dado, un mapa debe cumplir con **todos** los requisitos de ese nivel.
- Si un mapa no cumple con alguno de los requisitos de un nivel dado, entonces no pertenece a ese nivel sino a algún nivel más bajo.

Nota: Puede darse el caso de que un mapa de un nivel dado presente elementos de un nivel superior; sin embargo, sólo cuando presente **todos** los elementos de ese nivel superior podrá pertenecer a él.

Ejemplo de mapa conceptual de nivel 2



Ejemplo de mapa conceptual de nivel 5



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CREATIVE CONCEPT MAPPING: FROM REVERSEENGINEERING TO WRITING INSPIRATION

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Abstract. A semi-formal meta-analysis of current research into concept mapping suggests that very few teachers are using concept mapping to help their writing students create better essays or stories. Most studies tend to focus on "content-based" subjects such as math and science. However, there is also content, and, therefore, structure in literature and writing. While some students who read prodigiously have some basic grasp of this content, most do not. To help them first realize that there is such a learnable schema of content in my domain, students work through a series of concept maps. Starting with teacher-generated maps demonstrating the relationships among such argumentative strategies as claims and appeals and such literary devices as plot, character, setting and language, my composition and creative writing students, respectively, move on to generating their own maps, or completing scaffold maps, based on essays, short stories or films. Thus they begin the process of "reverse engineering," or "disassembling" essays and stories to analyze how their parts fit together structurally. Analyzing these primary sources teaches the basic components of exposition, argument and fiction in a more meaningful way than could be accomplished by lectures or "free for all" class discussion. From here, students use the maps as prewriting or planning documents. Finally, creative writing students use concept mapping as a peer- and self-critique device for workshop discussion and story enhancement.

1 Introduction

Researching a text on concept mapping, I printed and reviewed 380 abstracts of dissertations on the use of this technique for research, curriculum planning, learning and teaching, in subjects as diverse as mathematics, nursing, chemistry, biology, ecology and physics, as well as a few in literature and such far-flung fields as patient care, artificial intelligence, corporate training, fishing rights and medical patient education. Of these 380 abstracts, I selected 211 of the most relevant for an informal meta-analysis. After careful review, I labeled each study's assessment of concept mapping's efficacy according to the following categories: "tests and supports," "tests and denies," "inconclusive," and "applies." (A small number, <1%, analyzed various aspects of concept mapping itself, such as the comparative effects of stressing or not stressing cross-links, and so, weren't included in this analysis.) Of all abstracts studied, including those who did not explicitly test concept mapping as a teaching tool, 49% affirmed the technique, 10% denied its efficacy, and 6% showed unclear or questionable results, while 35% used concept mapping in data reduction or other qualitative and/or quantitative analyses.

Combining studies explicitly supporting concept mapping with those applying the methodology to other research tasks, since this is a tacit affirmation of the technique, showed 84% expressing a favorable opinion of concept mapping (49 and 35%), overall. The breakdown by subjects was most interesting: Of the 211 studies assessed, almost half (49%) researched concept mapping in sciences such as physics, biology, chemistry, and ecology, for instance. This is not surprising given the high level of government and workplace dissatisfaction fueling the widespread educational reform movement in these fields. In fact, several of these studies cite this reform movement directly as the primary impetus for their research.

2 General Conclusions of Meta-Analysis

While my book (actually being co-written with a former colleague) goes into far more detail on these results, suffice it to say here that science and math were concept mapping's "biggest clients," and that, while there were some naysayers among these "content-based" domain teachers, far more affirmed than denied its usefulness.

My allegedly non-content domain of literature and writing, however, was an entirely different matter. Despite the fact that essay writing was cited in studies as an alternative way to assess students' in-depth understanding of concepts in math and science courses, very few researchers (about 2%) showed much interest in applying the technique directly to fields requiring writing, such as literature or humanities classes. Although Novak (1999) discusses this possibility in relation to a student's reading and mapping of James Joyce's "Eveline" (p. 46) and planning a paper with concept mapping (p. 49), I found very little research applying concept mapping to composition or creative writing classes.[1]

2.1 Content- vs. "Non-Content" Subjects: a False Dichotomy

Because of its graphic nature, a concept map would seem to be the perfect learning and memory aid for such content-oriented subjects as science and math, for example. In fact, regarding memory and mapping, remember that "concept maps present a way to visualize concepts and the hierarchical relationships between them. Whereas most humans have a notoriously poor memory for recall of specific details, their capacity for recall of specific visual images is remarkable. . . . Concept mapping has a potential for enlisting this human capacity for recognizing patterns in images to facilitate learning and recall" (Novak, 1999, p. 28).

However, while the applicability of this structural aid to memory and understanding is obvious and well-researched in domains labeled "content-rich," it may seem less applicable to teachers of literature and writing, where creativity and inspiration are deemed more pertinent than content and structure. Much of this attitude, alas, is based on the philosophical schism that divides math and science, for instance, widely acknowledged to be content-based, from all the rest of us way over there, on the other side. These are the humanities courses, where, as one of my science-teaching colleagues expressed it, writing and grading the writing of others are "entirely subjective." According to this school of thought, there are no real facts, or, for that matter, any objective standards, upon which to test or grade student writing. For her, my field, unlike her own, is entirely subjective because it is "without content." However, all subjects have their domains; all have their store of ordered and interrelated concepts that we need to convey to our students. Being a structure-oriented humanities professor in a technological teaching environment puts me in a unique position to question these binary assumptions and try my own concept mapping experiments in all my classes, from technology and modern civilization to studies in literature, to composition, to creative writing. [1]

In fact, both content and, therefore, structure, obtain in my field; therefore graphic representation of both is equally applicable. Writing is also grasping and creating structure; writing also requires the mastery of a field of specific and learnable concepts. As Novak (1999) also states, "Every human activity, when carried to a point of sufficient proficiency, creates its own concepts, labels, words, actions, and ways of working and wondering that simply exclude the rest of us who are untutored in the events, objects, concepts, and facts about that activity" (p. 10). What's more, teachers in my field, just as in so many traditionally defined content-oriented domains, are also ". . . subject to the same rules as the students, and these are not the rules of an authoritarian hierarchy but of a shared structure of concepts - of shared meanings" (Volmink, qtd. in Novak, 1999, p. 11).

2.2 Concept Mapping in Literature and Writing Domains

If teachers and scholars ignore the content in my domain to hew to these harsh distinctions between "content to actually learn," and "no content to actually learn," how do we blame the students for showing the same attitude? Obviously, we can't, but what we can do is use such a structuring device as concept mapping to help counter this bias by demonstrating that, yes, literature and writing do have content and there are standards to learn in critical reading and in essay writing. By foregrounding my writing criteria, concept maps also help me make clear to my students that I don't grade their essays or stories subjectively according to how much they echo my own opinions or worldviews, but rather objectively according to how well they express their own thoughts in accordance with established standards of writing.

3 General Discussion of Concept Mapping in Writing Classes

3.1 Composition Classes

For me, the most content-oriented of my English classes are always the writing classes, particularly, composition, where students are expected to learn and practice the critical reading and communication, as well as problem-solving and collaborative learning skills, needed to carry them through all their college courses and beyond into a successful career "out there, in the real world." In practice, everything my students do can be seen as pre-writing exercises, from reading to mapping to planning their own critical response and argumentative essays. Emphasizing the pre-writing nature of concept mapping, and the fact that they count toward the "Gordon-Rule 6,000"[2], helps me convince students, from the outset, that concept mapping is of practical value to them. Otherwise, they might dismiss the

whole process as "busy work," especially in light of their already dismissive view of literature and writing, in general, as “contentless” and purely subjective. Thus, the mapping helps me to overcome some my students' natural bias, while getting them started in learning to summarize and critique the writing of others successfully according to a specific set of criteria.

In working toward my own understanding of good, clear persuasive writing, I have always been drawn to the specificity of rhetorical analysis which asks three very basic questions: 1) What is the writer trying to convince us of? 2) How is the writer trying to inform or convince; i.e. what strategies is he or she using? 3) How successful is the attempt to inform and/or to persuade the reader? The first question can be stated more specifically: what claims is the writer making? Claims are quite specific rhetorical gestures, divisible into four distinct types, factual, causal, value and policy. In beginning composition classes, students need to start by “reverse engineering” other arguments, successful and unsuccessful, before they can successfully structure their own critiques or original arguments. Applying these general questions to the source being critiqued supplies a ready-made conceptual scaffolding into which students can place specific critical observations on any argument. Linking these specific claims in a hierarchical structure, then, becomes the basis for a far more cogent and objective summary and critique of the original writer's ideas than one might otherwise hope for. Without such a structure, students tend to fall back on reacting in an emotional and subjective manner based upon the happenstance of their prior positions visa vi these new arguments. A concept map of actual claims and appeals can help students get past their first impulse to settle for a Jamesian “rearranging of their prejudices” to a real, well-considered and well-supported argument.

In addition, without such a conceptual structure, students tend to respond to the written argument by following its paragraph-by-paragraph structure, never creating their own order. In their attempt to superimpose critique over the source argument's established order, they create no organization of their own. Such response essays are a disorganized mess, showing, at best, a loose or associative order moving from one disconnected point to another.

Added to an argument’s claims and structurally linked to them in the following concept map [see Fig. 1] are Aristotle’s rhetorical appeals of *logos* (appeal to reason), *ethos* (appeal to trust), and *pathos* (appeal to emotions). While writers and speakers need to win over their audience with these appeals, it's also true that they do this for a purpose, to convince them of their various claims. At the same time, it is also necessary, in critiquing the writing of others, that students recognize not only the successful use of claims and appeals, but also the unsuccessful ones. Among these are many specific and well-defined rhetorical fallacies[3] that a writer might resort to, consciously or unconsciously, in an attempt to sway readers into accepting his or her claims through emotional manipulation or illogical arguments.

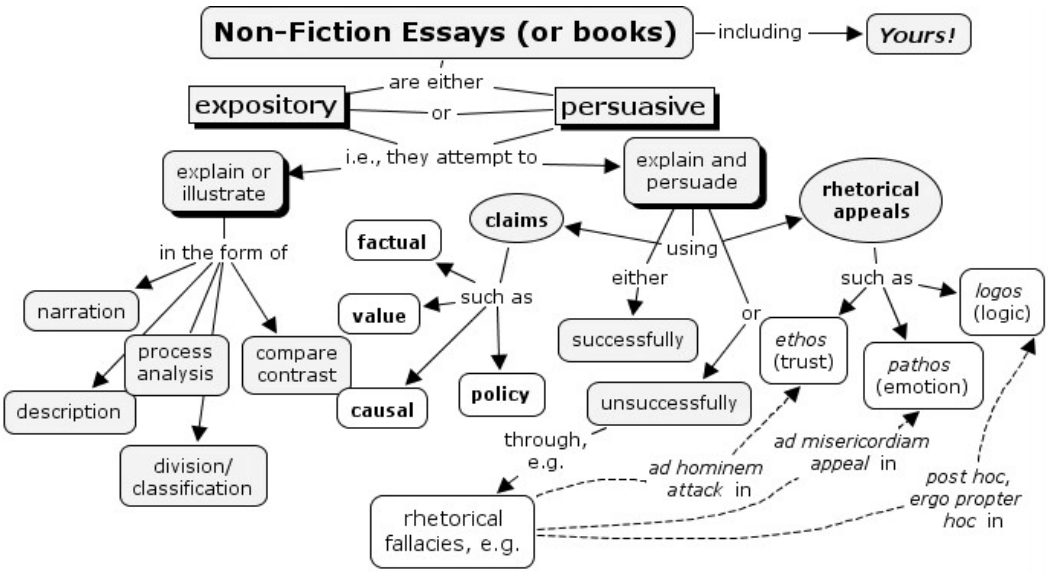


Figure 1. Teacher-generated concept map explaining distinctions between expository and persuasive writing, with claims and rhetorical appeals and some suggested connections between appeals and unsuccessful arguments

Through such maps, we briefly review basic distinctions between expository and persuasive (argumentative) essays, and then focus on argument. Following the hierarchical links from claims to the subsumed modes of factual, value, causal and policy claims; and from rhetorical appeals to the subsumed modes of *ethos, pathos* and *logos* gives my instruction and the students' critical readings, structure. Once they "see" the outline of the basic propositions included therein, such as, "Non-fiction writing either attempts to instruct readers through narration, e.g., or to persuade readers of claims through appeals such as *logos*," they are well on their way to assessing source essays and writing successful critical responses. Eventually, we add a variety of fallacies, easily subsumed as unsuccessful attempts at rhetorical appeals such as *ad hominem* attacks or *ad misericordiam* appeals. Poor organization and bad grammar, mostly in the students' own work, are eventually subsumed as bad *logos* or bad *ethos*.

As we gradually introduce the use of quotes and documentation as evidence, students turn their raw maps into critique-essay-planning documents. See Figure 2 for a student-generated example of such a pre-writing map.

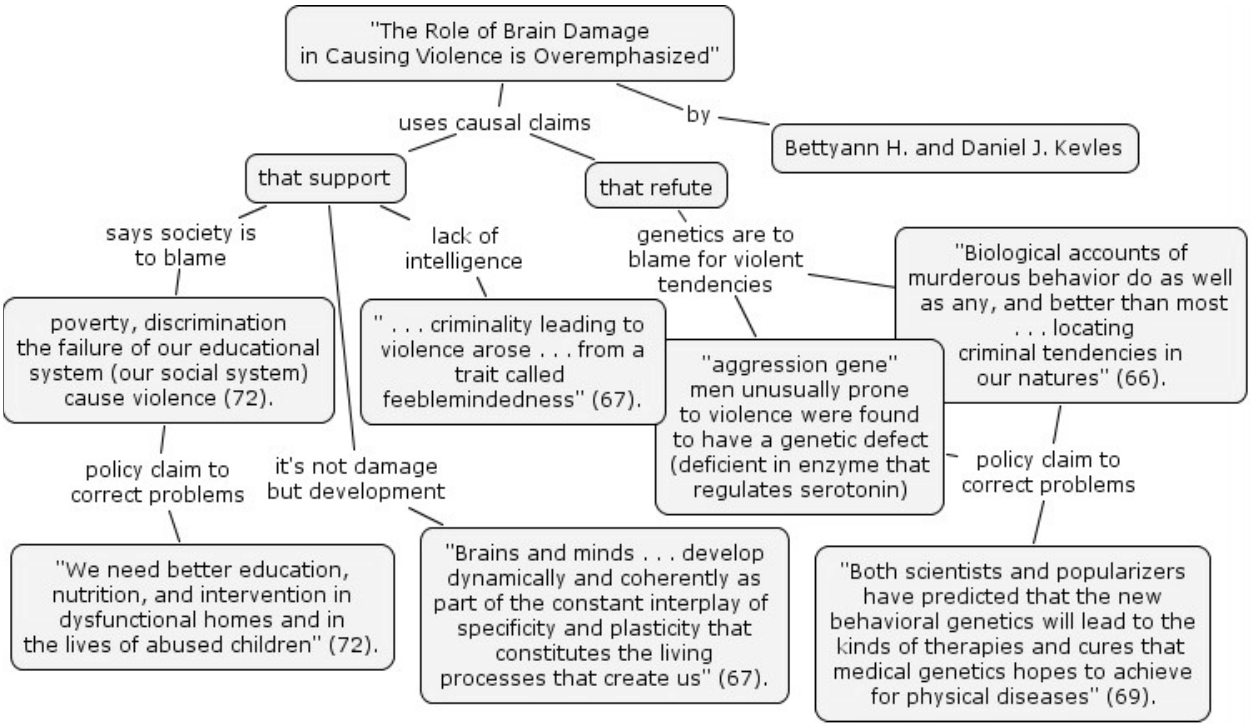


Figure 2. Student-generated map used to organize a critical essay assessing the use of claims in an essay from one of their required texts - Note the use of exact quotes and page numbers. (Used by permission.)

3.2 Concept Mapping in Literature and Writing Classes

In teaching creative writing, we do try to help our students find their inner wellspring of inspiration. However, to write well, one still needs to learn and understand a certain number of essential concepts. As such, part of learning to write successfully is learning to appreciate how other writers have used such concepts. Even here, therefore, concept mapping can prove invaluable for any student of writing, (and aren't we all always students of writing?), from "reverse engineering" a story to planning and/or enriching their peers' and their own stories.

3.2.1 Teacher-Generated Maps - Reverse Engineering as a Guide to Creativity

Novak (1999) writes,

> Undoubtedly, we may develop new concept relationships in the process of drawing concept maps, especially if we seek actively to construct propositional relationships between concepts that were not previously recognized

as related: Students and teachers constructing concept maps often remark that they recognize new relationships and hence new meanings (or at least meanings they did not consciously hold before making the map). In this sense, concept mapping can be a creative activity and may help to foster creativity. (p.17)

Indeed, in searching out a few of literature's universal lessons to share with my literature and creative writing students, I happened upon this central fact: contrast is the key to it all.

For my introductory literature classes, the devices through which writers express their themes are divided into concepts such as "plot," "character," "setting," and "language." Starting with these basics, the hierarchy sub-divides itself into enough subsumed concepts to produce a cogent and organized analysis of story, in general, and any specific story, as well. However, while revising this basic schema for my creative writing class, the very general concept of "contrast," in one form or another, began appearing, as if by magic, subsumed under all other subcategories. In other words, elements of contrast began popping up in plot, character, and language, generating a new map with "Contrast" as its most general topic of discussion, as seen in Figure 3, which follows. Contrast, through this new organization, emerges as the essence of creativity.

Even metafiction, in its interrogation of the relationship between fiction and real life, can be explained thus in terms of its sometimes singular contrast between plot expectations and actual outcomes. For instance, Joyce Carol Oates includes numerous tragic devices in her novel *American Appetites*, producing a tragic expectation that she intentionally thwarts with a rather absurd ending. Margaret Atwood's *The Edible Woman*, on the other hand, contrasts fairy-tale and two-suitor motifs with an unexpectedly "uncomic" and "unhappy" ending of a broken engagement. As a final example, Raymond Carver's "Cathedral" contrasts the majesty of its central symbol to the singularly unimpressive, almost puny, epiphany of its moderately insightful main character. Thus, the mapping process works either way, starting with the major concept then subdividing or reasoning backwards from many specifics to a new major concept, such as contrast.

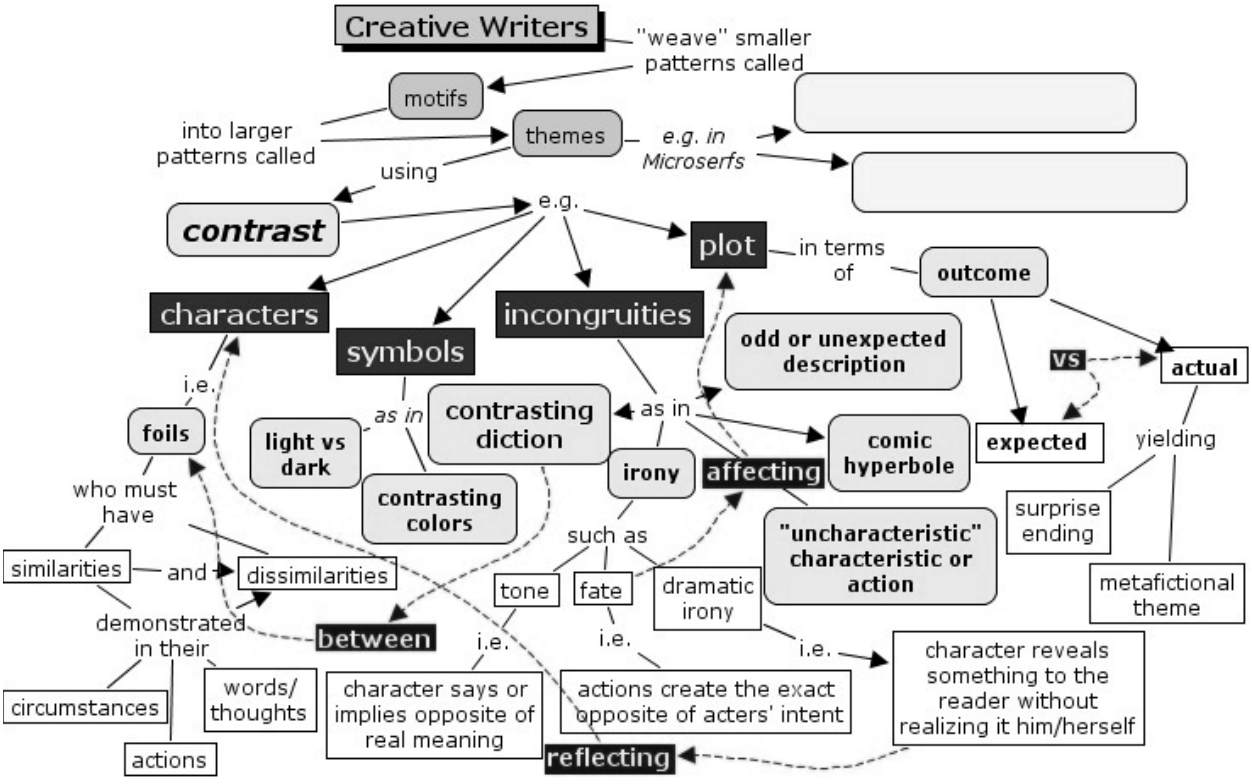


Figure 3. Writers' use of contrast in terms of plot, character and symbolism, e.g., with some blanks for workshop discussion.

This newly emerged hierarchy helped me bridge the gap from literary analysis to creative writing by yielding a new "reverse-engineering" device; once the student has recognized contrast as an important device in the plots,

characters and/or symbolism other writers have used, students can see more clearly how to enhance their own, "borrowed from reality" stories. There's a paradox, however, in moving students from critical analysis of extant stories to creating their own. For those inexperienced in learning and applying the writing lessons of others to their own work, there is a tendency to treat plot and characterization in the stories they've read as if they were all foregone conclusions. At the same time, they seem to view their other source of inspiration, their own real-life stories, as just as concrete and foregone. In other words, they get stuck in the factoids of their lives and fail to explore the possible truths art about their lives could reveal.

3.2.2 Student-Completed Scaffold Analysis Maps

One concept mapping technique I've been developing to resolve these conflicts, using my own "node heuristic" of creativity, is discussed in depth and exemplified in another paper. Here, I wish to discuss an alternative exercise using a combination of literary analysis, film discussion and scaffold concept mapping focused on one crucial use of contrast in story structure, the character foil. Beginning literature students tend to gloss over the writer's carefully constructed "compare-contrast" structure of characterization. By the same token, so do beginning writers. Understanding character foils can help creative writers add the contrast and structure most lives lack to constitute interesting stories.

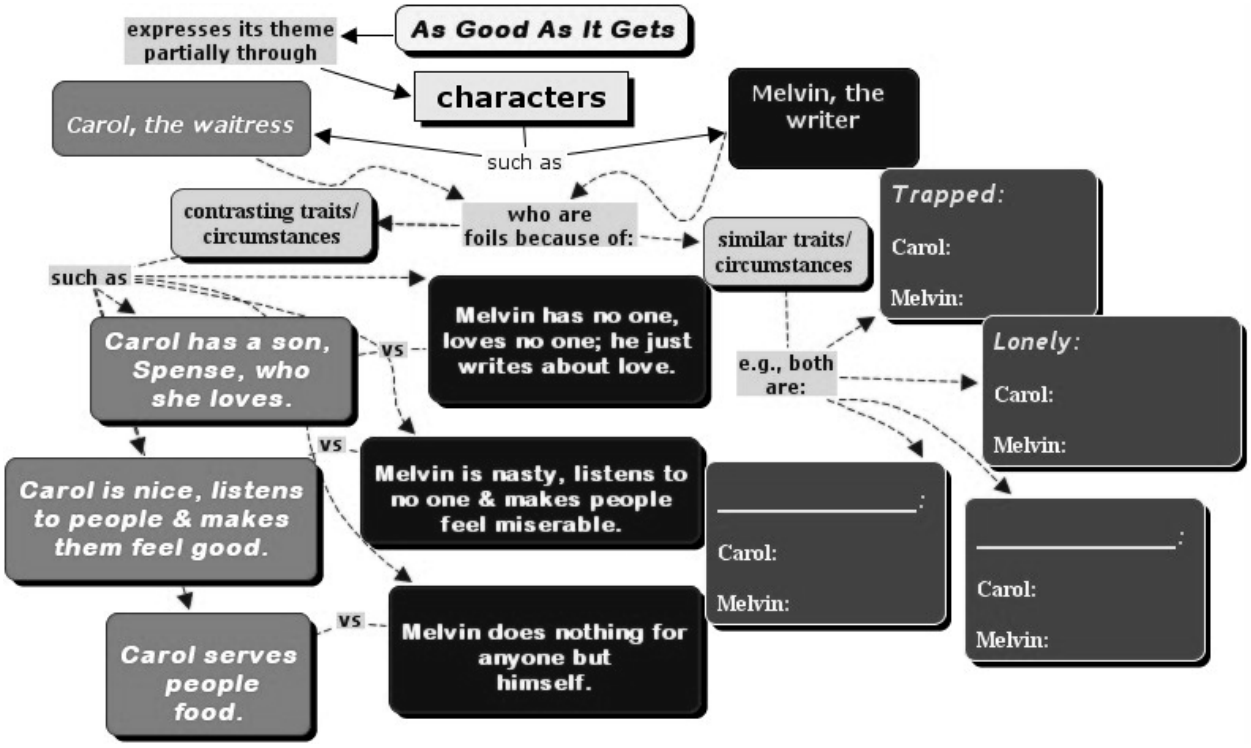


Figure 4. Partially completed scaffold map allows workshop groups to collaborate on discussion of character traits

After screening part of the film *As Good As It Gets*, my creative writing class divides into small workshops to reverse engineer its character structure to reveal how contrasting characters can add conflict and drama to their own stories using scaffold maps such as Figure 4, above. Careful placement highlights the characters' common and contrasting elements, such as the commonalities and contrasts between Carol and Melvin. It works equally well with other character pairs, such as Simon, the artist and Melvin or Simon and Carol. Cross-links on such a concept map can also help students tease out the motifs and themes of the story. Creative writing students can use blank scaffold maps to go beyond this analysis to apply the same principals in a creative way to their peers' and their own stories, in other words, to move from reverse engineering to creative use of structure. Naturally, to help the workshop process along, constructivism meets the Socratic method in such questions as, "What is the central element that leads to the redemption stories of Melvin, Carol and Simon?" and "What do Melvin's compliment, 'You make me want to be a better man,'" and his sending a doctor to examine Carol's son, Spense, have in

common?" With a little effort, students can see the cross-links among these separate acts and bits of characterization, and through the effort of cross-linking them on a map, find a label that works, such as "acts of intimacy and acts of kindness," illuminating another structural element of story, motif.

3.3 Peer- and Self-Critique Scaffolds

The next obvious step is to apply elements of character and plot to specific, original stories to help my students critique each other's work and to add more structure, conflict and drama to their own. The following invites further insight and creativity in terms of characterization and plot and their interactions.

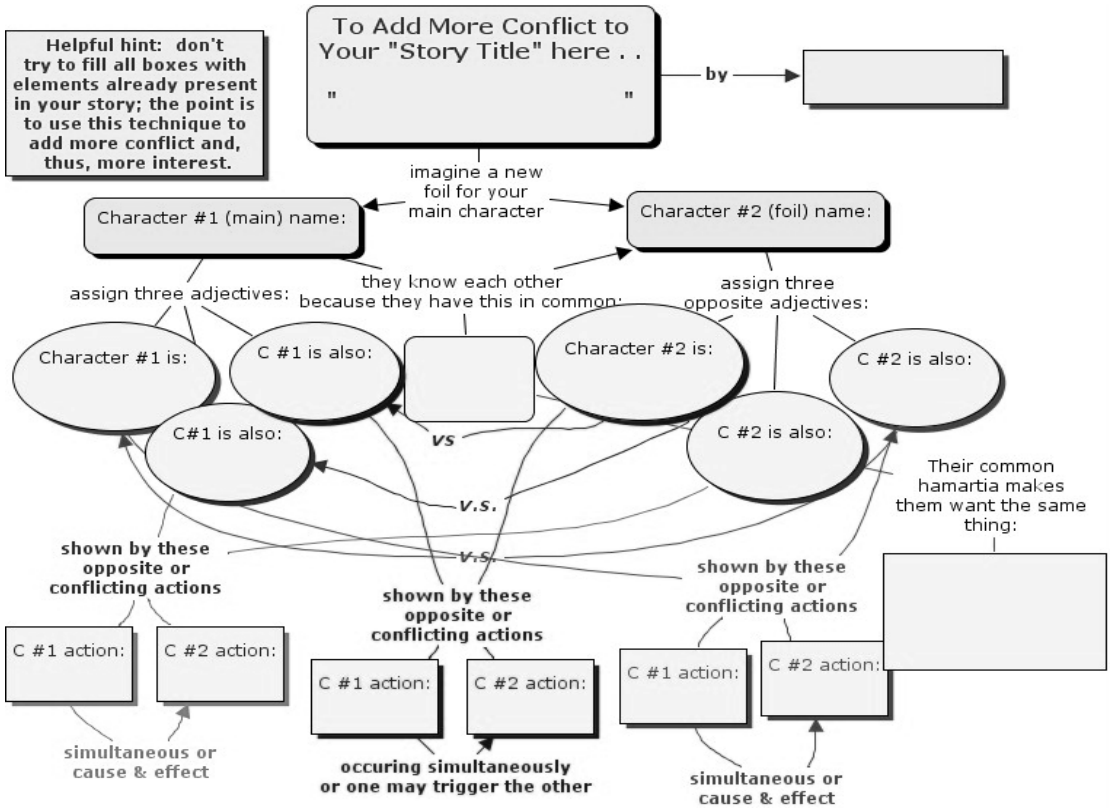


Figure 5. Scaffold map filled in by creative writing students for peer and self-critique (*Hamartia*, Greek for "characteristic," is often mistranslated as "tragic flaw.")

4 **Summary**

The structured, hierarchical nature of concept maps has proven useful in all stages of non-fiction and fiction writing classes. After a brief introduction in the form of teacher-generated maps explicating the basic and subsumed aspects of expository, argumentative and literary writing, students move on to their own analyses of extant works. Following this reverse engineering process, students add direct quotes and documentation to their maps to transform them into planning documents for their own essays. Using this heuristic process has resulted in writing, based on analysis of both fiction and non-fiction, which is more rigorous in structure and more objective in content; as well as fiction that is richer and more interesting than that produced without it. Finally, students absorb the lesson that humanities courses also have their content to communicate and apply these lessons to writing, critiquing and revising essays and short fiction.

Notes

1. While there are such mapping techniques as "The Captain Correlli Character Frame," included with the *Conception* package (available at www.parlog.com), lacking structural rigor, it does little to clarify the relationships among a story's separate facets. Therefore, it does not work to "reverse engineer" extant, or to structure new, essays or stories.
2. The Gordon Rule is a state-wide agreement in Florida, similar to agreements in other states, that freshmen and sophomore writing students require at least 6,000 words in writing assignments per semester to improve their writing.
3. Since not all fallacies are failed attempts at logic at all, I resist the standard label "logical fallacies."
4. Due to space limitations, only a small sample of dissertation abstracts reviewed is included in this list; the entire list is available upon request.

References

Atwood, Margaret. (1996). *The edible woman*. New York: Bantam Books.

Carver, Raymond. (1983) Cathedral. In Stanford, Judith A., (Ed.), *Responding to literature: stories, poems, plays and essays*, 4th Ed. (pp. 516-527). Boston: McGraw Hill.

Churlarut, Pasana. (2001). The influence of concept mapping on achievement, self-regulation, and self-efficacy in students of English as a second language. (Doctoral dissertation, University of Oklahoma, 2001). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 30044889)

Harper, Ralph L, Jr. (2001). The professionalization of logistics: A management specialty to meet 21st century challenges. (Doctoral dissertation, Nova Southeastern University, 2001). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3015882)

Hinton, Juliana G.(2000). A narrative study of selected introductory college biology students' struggles to gain an understanding of scale and measurement. (Doctoral dissertation, Louisiana State University and Agricultural & Mechanical College, 2000). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9991749)

Kevles, Bettyann H. & Kevles, Daniel J. (1997). The role of brain damage in causing violence is overemphasized. In Laura K. Egendorf (Ed.), *Violence: Opposing viewpoints* (pp. 64-72). San Diego: Greenhaven Press.

Novak, J. D., & Gowin, D. B. (1999). *Learning how to learn.* New York: Cambridge University Press.

Oates, Joyce Carol. (1990). *American appetites*. New York: Harper & Row.

Osman-Jouchoux, Rionda. (1997). The use of concept mapping tactics in cognitive strategies for writing summaries of technical material. (Doctoral dissertation, University of Colorado at Denver Graduate School of Public Affairs, 1997). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9804545)

Roop, Kimberley M. (2002). Effect of concept mapping as a learning strategy on certificate practical nursing students' academic achievement and critical thinking development. (Doctoral dissertation, Wilmington College, Delaware, 2002). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3047529)

Steele, Ann Marie. (2001). The effect of the length of class time on high school mathematics teaching strategies. (Doctoral dissertation, Temple University, 2000). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 3014484)

Sturm, Janet M. (1996). Effects of hand-drawn and computer-generated concept mapping on expository writing and writing attitudes of middle level students with learning and reading disabilities. (Doctoral dissertation, The University of Nebraska, Lincoln, 1996). Abstract retrieved September 11, 2003 from ProQuest – Dissertation Abstracts on-line database (Item AAC 9715987)

Zea, Kristi. (Producer), & Brooks, James L. (Director). (1997). *As good as it gets.* [Motion picture videocassette]. USA: Sony Pictures.

Concept Maps: Theory, Methodology, Technology
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A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

DEVELOPING A CONCEPT MAPPING APPROACH TO MATHEMATICS ACHIEVEMENT IN MIDDLE SCHOOL

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Abstract. Concept mapping has been very useful in a variety of disciplines; however, there has been relatively little use of it in mathematics in the United States. A project to bring the use of concept mapping into middle grades mathematics was begun at the University of North Florida (UNF) in the spring of 2005, and has produced a design for a two-week, summer middle grades mathematics camp for delivery in the summer of 2006. Preceding the camp is a series of teacher professional development workshops provided for the (middle school) teachers of the camps. The workshops focus on the use of concept maps in planning, classroom delivery, and assessment; on the use of the CmapTools software; and, on the development of activities appropriate to Algebra I topics or readiness, and also which integrate a concept mapping component. This paper describes the development process, the instruments developed, the summer camp itself, and planned follow-up during the 2006-2007 school year.

1 Introduction and Overview

In early spring 2005, the Florida Institute of Education at the Unversity of North Florida (FIE) joined in a partnership with the Institute of Human and Machine Cognition (IHMC) with the goal of bringing the use of concept mapping into middle grades mathematics. FIE was already engaged in a middle grades mathematics enhancement program called the PreCollegiate Program. The partnership with IHMC was formed to bring concept mapping into that program through the use of CmapTools[1] software.

A team of three UNF mathematics faculty members, two high school teachers experienced in teaching Algebra I, and two FIE professionals comprised the development team (hereinafter, the team), and during the period May-July, 2005, IHMC provided the team with extensive training in the use of CmapTools. Throughout the remainder of the calendar year, the team focused on designing and writing a set of expert maps describing Algebra I as a connected set of mathematical concepts. The following protocol was established by the team: *In every expert map produced, any 3-element sequence of concept-connector-concept must stand alone as a correct and mathematically meaningful sentence.*

During the spring of 2006, the team worked with two independent Florida School districts, Polk County Schools, and Duval County Schools (in Florida, each county represents a single school district) to plan summer mathematics camps for high-risk middle school students from low-performing middle schools in each district. This planning was accomplished through a series of four teacher-development workshops and several follow-up planning sessions. The workshops were conducted by the team, and were open to all middle school mathematics (and science) teachers from the participating schools in each district.

The summer camps had three primary objectives:

i. to increase the interest of the participating students in learning about mathematics and its applications;
ii. to improve the readiness of the students for entering and succeeding in Algebra I; and,
iii. to introduce concept mapping, through CmapTools, as a mathematics teaching, assessment, and learning strategy.

Four full-day workshops were designed to have the teachers learn to use CmapTools and also to have the teachers develop well-organized mathematics and applied mathematics activities that were designed to

i. increase student interest in learning mathematics;
ii. focus on well-defined mathematics objectives that were related to Algebra I; and,
iii. introduce concept mapping as a component of the teaching and learning strategy.

[1] http://cmap.ihmc.us

The summer camps were designed in April and May, 2006, and then delivered in June.

2 Concept Mapping of Algebra I

The approach taken to defining Algebra I for mapping purposes was to first decide on the major concepts to be featured. The major concepts selected by the team were:

Equations and their solutions
Inequalities and their solutions
Concepts associated with exponents
Polynomials and rational expressions
Functions
Graphing

An expert map connecting these major concepts, related sub-concepts, and essential prerequisites was developed by the team in the fall of 2005, and modified as the project developed over the spring 2006 term. The current Algebra I master map is given in Figure 1.

Each of the sub-concepts identified in the master map was mapped by the team, and was connected through CmapTools to the master. Each map created was revised many times before reaching its current state. These maps are expert maps, and are not intended as fundamental teaching tools to be read by the students. Rather, they are for review and reference by the teachers as they examine their individual understanding of the mathematical concepts associated with Algebra I and the connections among those concepts.

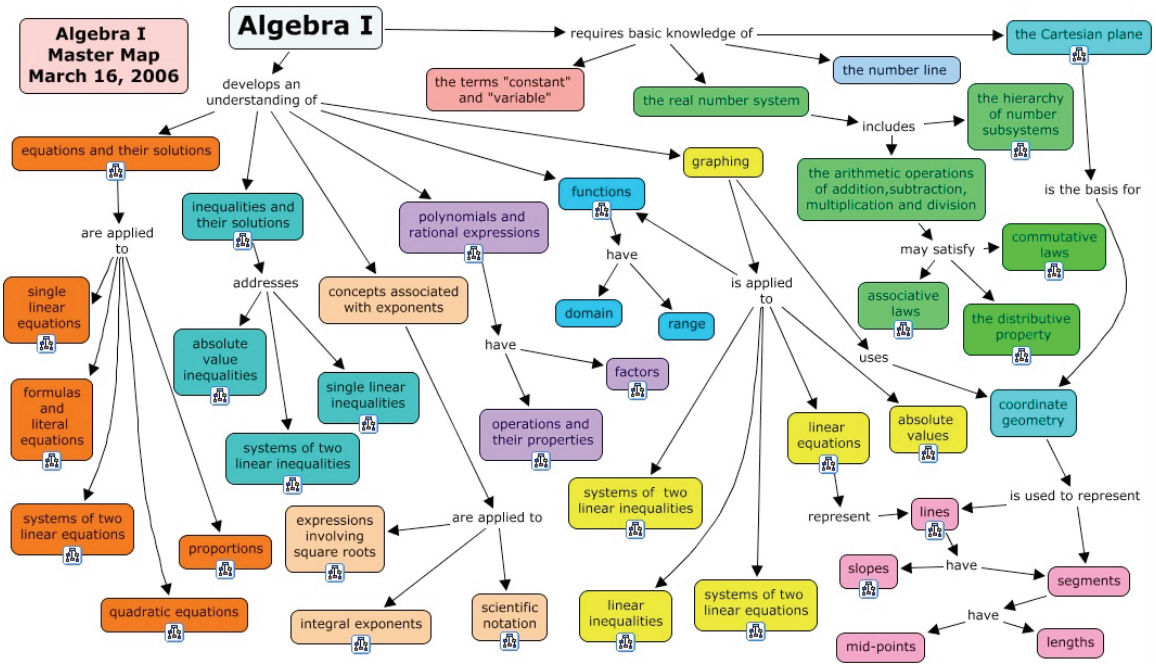


Figure 1. Algebra I Master map.

The protocol established by the team was that any sequence of concept-connector-concept should read independently as a complete, correct, and meaningful sentence. This restriction was adhered to as much as possible, and sometimes led to maps that were somewhat more complex than was hoped for by the team. An example is given in Figure 2.

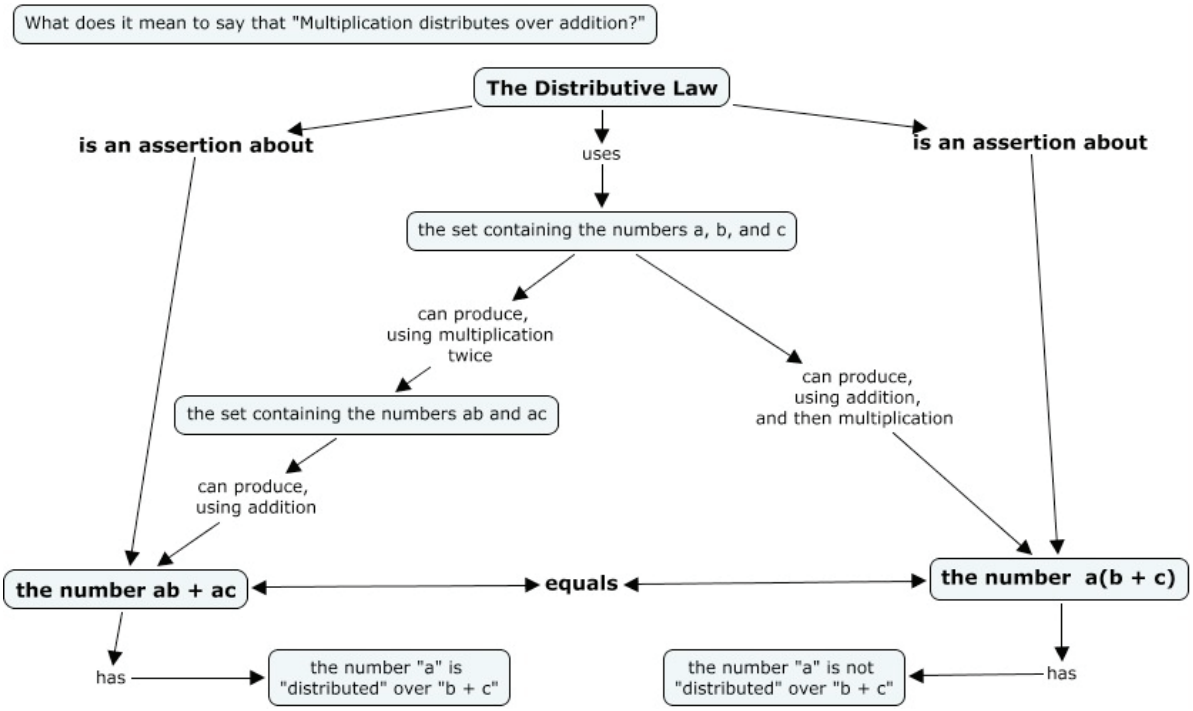


Figure 2.

Despite this possible consequence, the team felt that adherence to the protocol forced one to think carefully and correctly about the concepts that were being connected, and also what was really the most appropriate connection, so the protocol was maintained.

While developing the Algebra I expert maps, the team observed that a mathematics concept map node had three possible kinds of objects that could be connected to it to provide useful information about, and understanding of, the concept. These were: other concept maps; examples of things that satisfied or described the concept; and, in some cases, how to perform processes associated with the concept. The last of these, processes, lent itself easily to being described through the CmapTools software, and the team developed some important process maps to be connected to the master and other maps, as clarifying objects.

3 The Workshops

The four teacher development workshops each were for a full day, and each included: discussion of concept mapping; time for using CmapTools; work on a typical summer camp activity; and a discussion of the activity's mathematical focus. Figure 3 gives a typical workshop schedule.

Polk County / FIE Summer Camp Workshop III **Boone Middle School** **Agenda** **March 11th, 2006**	
8:00 – 9:30	Large number activities: *Arranging Books* *Drips of Water*

9:30 – 10:00	Discussion of the number sense activities
10:00-11:45	Teams build concept maps of large numbers – A planning application
11:45 – 12:00	Discussion: Summer Camp 2006
12:00 – 12:30	Lunch
12:30 – 1:30	Review of an activity from last year's summer camp *Packaging and the Environment*
1:30-2:45	CmapTools work – Connecting the mathematical concepts in a chapter of a typical text
2:45 – 3:00	Evaluation

Figure 3.

In one workshop, the team presented the teachers a concept map constructed for Unit 2 of the CPM Algebra I text (Figure 4). Afterward, the teachers constructed a concept map of all basic mathematical concepts in a single chapter of a text they currently used in one of their classes.

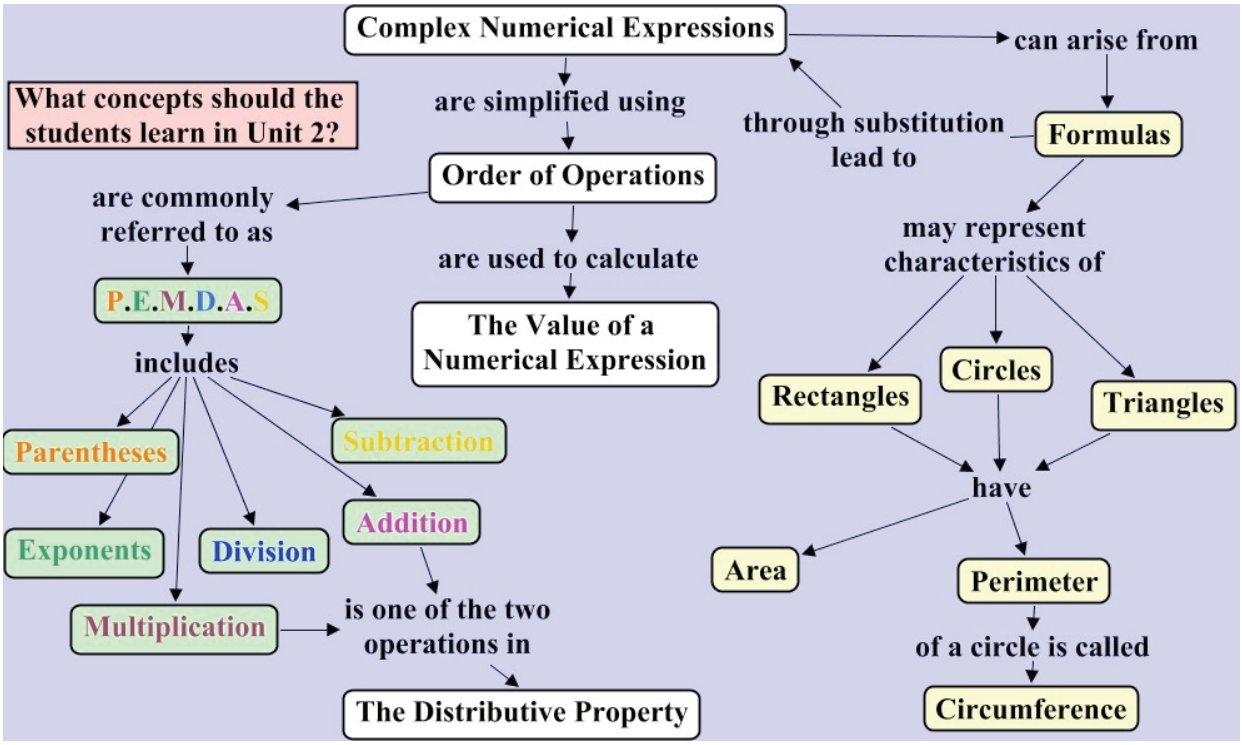


Figure 4.

When asked how they could help students appreciate the size of 1 million, the teachers came up with some interesting process maps, one of which is given in Figure 5.

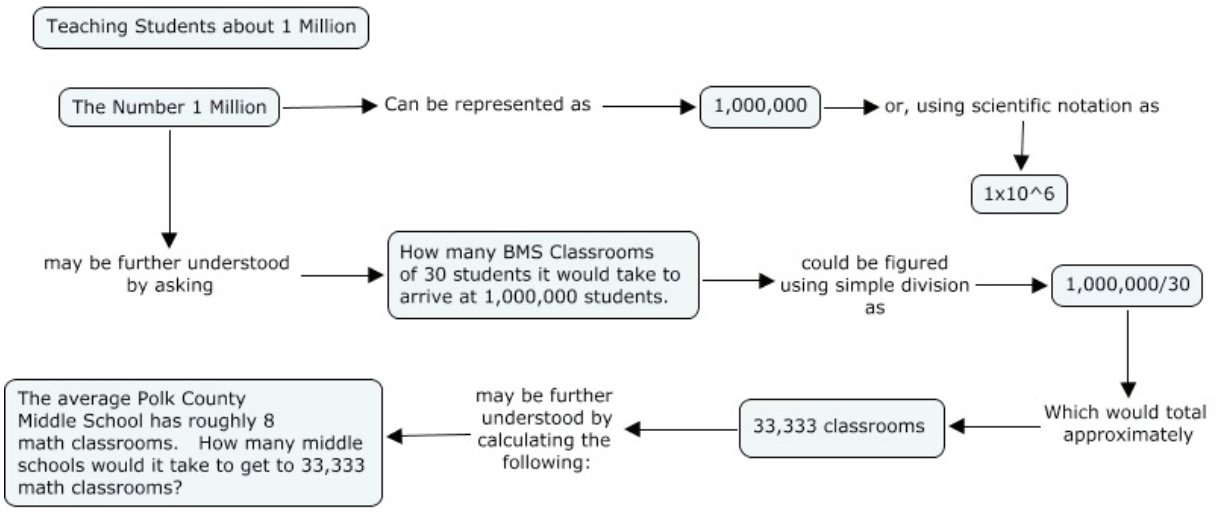


Figure 5.

4 The Summer Camps

The summer camps were developed from a bank of activities that were produced by teachers in the PreCollegiate Program over the years of its operation. A typical activity is *Timing the Circle.*

"Timing the Circle"

Activity Description:

A 40-foot diameter circle is laid out in an open field, and a diameter is indicated. Starting at one end of that diameter, a student walks at a steady pace around the full circle. The time elapsed for the circuit is recorded. Then, the same student walks at the same steady pace from one end of the diameter to the other, again recording the elapsed time. Once all students in the class have performed this same activity, each student calculates the quotient of his/her time to go around with time to go across the circle. The students than compare the numbers they have calculated. The experiment is repeated for a different circle. If a student's individual speed has been uniform for walking the diameter and walking the circumference, the numbers calculated will be reasonable estimates for π.

Mathematical Vocabulary Introduced:
Circle
Center of a circle, O
Diameter of a circle, D
Circumference of a circle, C
Radius of a circle, R
The number π

Mathematical Relationship Discussed:
$C = \pi D = 2\pi R$

Physics Formula Discussed:
Distance = Rate x Time

Mathematical Goals of the Activity:
1. To have the students understand basic properties of circles.
2. To have the students discover that the ratio of the circumference to the diameter of a circle is constant, and to estimate what that constant is.

3. To introduce to the students a relationship between physics and mathematics.

Equipment Required:

If circles cannot be marked out using a standard sports-field line marker, materials to make them will be required. Construction tape or marking flags can be used.

Stopwatches
Tablet/pencils
Calculators

Conducting the Activity:

A discussion of properties of circles should take place either in class on the day of the activity, or on the field immediately before the activity begins. A table with each student's name and columns for entering times across and times around should be prepared in advance. The circles also should be set up in advance. Once on the field and ready to start the activity,

1. Discuss what will take place, and emphasize the importance of keeping a steady pace and of using the same pace going across as around the circles.

2. Assign some students to be timers, and some to be recorders. Two timers should be used for each student, and a walk repeated if the two stopwatch times are too far apart.

3. Have the students walk around a circle then across the circle at the same pace, timing the walks and recording their results on the table. If there is enough time, have each student walk it twice, at different rates of speed.

4. Once all students have walked, calculate the time around divided by the time across for each row of the table.

5. Get everyone involved in calculating the quotients. The calculations can be done on the field or back in the classroom, but should be done so that everyone can compare their own numbers with those of others. Calculate a class average and compare it with π.

6. Discuss how the quotient of two *times* can give the same thing as the quotient of the two *distances* – the circumference and the diameter.

7. Have students complete worksheets giving some practice with calculating circumferences (e.g., calculating hat size, or showing what happens to the circumference when changes are made in the diameter).

8. Use the Vocabulary List to have students prepare a concept map with the circle as the basic concept.

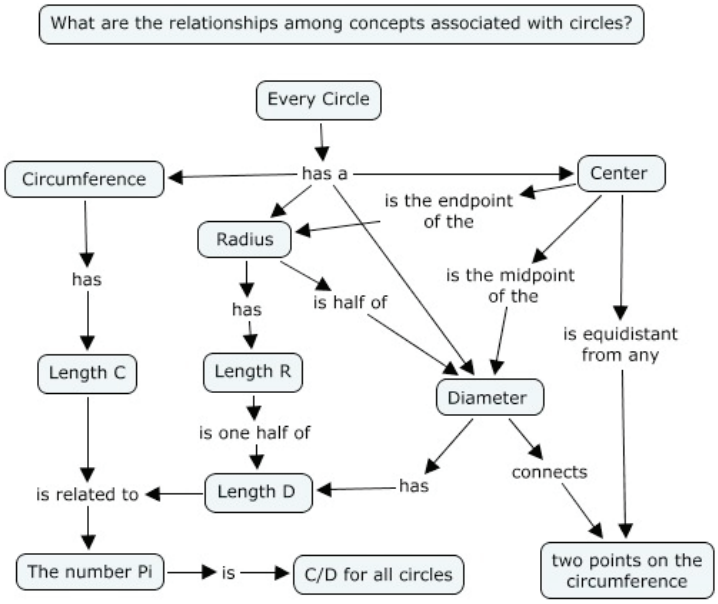


Figure 6: Possible Expert Map for *Timing the Circle*.

Each activity is organized in a fashion that states clearly the mathematical objectives of the activity, the connection of those objectives to appropriate standards, a method for carrying out the activity, the basic mathematical concepts involved, and a concept map of those ideas. Camps were scheduled for two, five-day weeks, and each included 35-40 students. Each camp was conducted by middle school teachers, with several team members acting as consultants each day. Both the teachers and the students received stipends for participating in the camps. A pre/post test was conducted to indicate the impact of the camp on the students.

5 Project Continuation, Fall 2006

The primary purpose of the project is to have impact on the students' performances in mathematics, and to encourage them to apply themselves more to their mathematics courses. To keep this encouragement active, the teachers from the camps will introduce concept mapping into their regular classrooms beginning in the fall of 2006. The FIE Team will visit classes and will consult with the teachers over the course of the year, and the FCAT[2] results from 2006 to 2007 for participating students will be compared with the change for non-camp students with comparable scores in 2006, to see if there was any impact from the camp and the subsequent concept mapping instruction.

The Algebra I mapping project will be completed in the fall of 2006, and a series of professional development workshops based upon those expert maps will be developed for delivery at several sites throughout Florida in the spring of 2007.

6 References

Algebra I. Schultz, J and Kennedy, W. Holt, Rinehart and Winston, 2004.

Algebra I, Sallee, Kysh, Kasimatis, & Hoey; CPM (College Preparatory Mathematics) Series, Vol. 1 & Vol. 2, 2002.

Algebra I, James Schultz, Paul Kennedy, Wade Ellis, Kathleen Hollowell, Holt, Reinhart and Winston, 2004.

Learning, Creating, and Using Knowledge, Novak, J.D., Lawrence Erlbaum & Assoc. 1998.

Learning How to Learn. Novak, J.D. and Gowin, D.B. Cambridge University Press, 1984.

[2] * The Florida Comprehensive Assessment Test (FCAT) is the official measure of student performance administered by the State of Florida each spring.

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DISEÑO CENTRADO EN EL USUARIO DE UNA HERRAMIENTA PARA QUE USUARIOS NO VIDENTES CONSTRUYAN MAPAS CONCEPTUALES

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Abstract. Los mapas conceptuales han sido utilizados en las últimas décadas como una técnica efectiva para la construcción de significado. En la educación, por ejemplo, los mapas han sido clave para apoyar el aprendizaje significativo en el aula. Sin embargo, su naturaleza gráfica restringe la utilización por parte de aprendices con discapacidad visual. Por esta razón, basándonos en nuestra experiencia en el uso de tecnologías interactivas basadas en audio para apoyar el desarrollo cognitivo de aprendices ciegos, hemos desarrollado AudiodMC, un editor de mapas conceptuales basado en sonido para usuarios no videntes. En este trabajo se muestra cómo un diseño de software basado en el usuario permite construir una herramienta que se ajusta a las necesidades, intereses y formas de interacción de estos usuarios. Describimos, analizamos y discutimos las tres etapas que conformaron nuestra investigación: observación de usuarios, diseño de software y evaluación de usabilidad. Finalmente, discutimos las proyecciones del uso de AudiodMC como herramienta para apoyar la construcción de significados en aprendices ciegos.

1 Introducción

Los mapas conceptuales son instrumentos que pueden llevar a profundas modificaciones en la manera de enseñar, evaluar y aprender (Novak y Gowin, 1984; Novak, 1998). Procuran incentivar el aprendizaje significativo y entran en conflicto con técnicas dirigidas al aprendizaje mecánico (Moreira, 1998). El aprendizaje significativo implica que el aprendiz haga suyo un nuevo contenido a partir de las relaciones que establece con saberes previos, bajo condiciones de significatividad lógica, psicológica y una actitud activa y de motivación. Aprender es establecer relaciones de significado (Ausubel et al., 1978). Ausubel entiende que una teoría del aprendizaje escolar que sea realista y científicamente viable debe ocuparse del carácter complejo y significativo que tiene el aprendizaje verbal y simbólico. Con el objeto de lograr esa significatividad, debemos prestar atención a todos y cada uno de los elementos y factores que afectan al aprendiz y que pueden ser manipulados para tal fin (Rodríguez, 2004).

Un mapa conceptual es una expresión gráfica de las relaciones de un conjunto de conceptos y la naturaleza de éstas. Nos permite, de una sola vez, identificar los conceptos más relevantes de un contenido, relacionarlos y organizarlos jerárquicamente, generando una representación gráfica de los esquemas mentales asociados a dicho contenido (Novak & Gowin, 1984). Los mapas conceptuales son una forma de poner en práctica el aprendizaje significativo, pero su aplicación requiere de cierto entrenamiento previo.

Asistir la construcción de mapas conceptuales a través de software para diseñar acciones pedagógicas significativas, es una idea que permite facilitar y orientar la tarea, centrándose en los usos y propósitos del aprendizaje significativo y minimizando la complejidad de la técnica (Novak, 2003). Existe también cierto consenso acerca del aporte de las tecnologías al diseño y uso de mapas conceptuales. Un ejemplo de esto es CMaptools, herramienta altamente utilizada para la creación de mapas conceptuales (Cañas et al., 2004). Este software posee un modelo que permite publicar los mapas para ser editados de manera colaborativa por varios usuarios a través de la Web. Concept Conector (Luckie et al., 2004) es una herramienta diseñada para estudiantes de ciencia para representar el conocimiento y recibir feedback inmediato de su diseño. CM-ED (Rueda et al., 2004), es una herramienta que permite la edición de mapas a través de plantillas con distintas vistas y con multilenguaje. dMC (Sánchez & Alarcón, 2004) es una herramienta que permite tanto a estudiantes como a profesores negociar el diseño de mapas conceptuales por medio de la red, con sesiones de trabajo en el aula y comunicación asincrónica.

El mapa conceptual es visto por algunos autores como un instrumento cognitivo para el desarrollo de los procesos de pensamiento y más concretamente del pensamiento crítico, tales como: analizar, organizar, sintetizar, comparar, evaluar y diseñar (Novak & Gowin, 1984; Novak, 2003; Moreira, 1998; Ramos, 2004). La efectividad de un mapa se deriva de su capacidad para visualizar el pensamiento y sus estructuras de conocimiento, sumado a ello que los conocimientos están organizados semánticamente en la memoria, lo que justifica todavía más el uso de los mapas como instrumentos de visualización de estructuras (Tascón, 2004). El impacto visual de un mapa conceptual es considerado importante ya que muestra las relaciones de uno o más conceptos (Ramos, 2004).

Previo a la construcción de un mapa conceptual un aprendiz debe aprender que los objetos existen, que tienen permanencia y difieren unos de otros, identificarlos, nombrarlos y definir sus características, además de identificarlos como objetos enteros. A partir de las experiencias sensoriales el aprendiz abstrae elementos comunes, construyendo y generalizando la formación de un concepto cuyo significado incrementa en la medida que pueda relacionarlo con otros conceptos. Todo este proceso se basa fundamentalmente en experiencias sensoriales, en un mundo donde dichas experiencias son esencialmente de orden visual.

Es en virtud de ello, que un aprendiz ciego se encuentra en desventaja en cuanto a la calidad y cantidad de información del medio que percibe y en la construcción conceptual del mundo que lo rodea. La mayoría de los estudios realizados sobre la psicología de la ceguera afirman que no debe establecerse una psicología "especial", distinta a la del vidente. Los ciegos no constituyen una población homogénea cuyas características puedan describirse en contraste con la población vidente; disponen de recursos físicos y psicológicos básicamente similares a estos con la excepción de la vista, lo que los hace ser una población con características cognitivas particulares debido al modo cómo reciben y almacenan la información del medio (Alderete, 1988). Existe consenso en que el déficit cognitivo que pueda tener un aprendiz ciego sin deficiencias asociadas, se debe más a la carencia de estimulación que a la falta de visión. El niño ciego no es un vidente que carece de visión, ya que su manera de percibir el mundo no es igual a la de un niño normal privado de vista. La diferencia estriba en la organización original que opera en sus modalidades sensoriales (Ruiz, 1997).

Pensar que un aprendiz ciego pueda construir un mapa conceptual supone varios desafíos a investigar, ¿Cómo logra un ciego dar significado conceptual al mundo que le rodea?, ¿Cómo incorpora la información de un mundo eminentemente cargado de estímulos visuales?, ¿Cómo almacena esta información?, ¿Cómo construye una representación gráfica de sus significados? Se podría suponer que la construcción de un mapa conceptual, dado su carácter gráfico y visual, puede estar negada para un aprendiz ciego, de hecho la literatura especializada hace casi nula mención a experiencias de este tipo.

En la última década que nuestro grupo ha investigado el impacto de interfaces de entornos de software interactivo audibles en el desarrollo cognitivo de aprendices ciegos. Como resultado, hemos detectado que, con el apoyo de interfaces basadas en sonido diseñadas específicamente para niños ciegos, es posible estimular el desarrollo de estructuras cognitivas de dominio general y específico (Sánchez & Lumbreras 1999; Sánchez & Flores, 2004; Sánchez & Sáenz, 2005). Sobre la base de esta experiencia, decidimos construir una herramienta basada en audio que facilite el acceso de aprendices ciegos a la construcción de mapas conceptuales.

La propuesta de investigación que presentamos en este trabajo apunta a desarrollar una herramienta multimedial que por medio de audio, permita a los aprendices ciegos construir mapas conceptuales, basándose en la forma cómo ellos organizan naturalmente sus conceptos. Creemos que un audio depurado, bien especificado y eficaz, puede permitir al ciego adquirir ciertas habilidades de codificación y selección que son útiles para su aprendizaje, específicamente para la organización cognitiva de conceptos.

2 Metodología

El objetivo central de este estudio exploratorio fue diseñar y desarrollar una herramienta centrada en el usuario que permita a aprendices ciegos construir mapas conceptuales.

Etapas. El estudio fue desarrollado en tres etapas: 1. Observación de los aprendices, 2. Diseño de AudiodMC, y 3. Evaluación preliminar de la usabilidad de las interfaces.

2.1 Observación de los aprendices

Se seleccionó una muestra intencionada de aprendices. El criterio de selección de la muestra fue que los aprendices cumplieran al menos con el 50% de los siguientes requisitos: Poseer un coeficiente intelectual no inferior a 70, manejar el teclado a nivel de usuario, poseer un lenguaje expresivo y comprensivo por lo menos a nivel literal y utilizar efectivamente su sistema lectoescritor, ya sea braille o macrotipo. La muestra quedó constituida por 11 niños ciegos legales de 5° y 6° año de enseñanza primaria. Según su diagnóstico psicológico el 73% tiene un CI normal y

el 27% es limítrofe. El 100% de ellos maneja el teclado. El 82% utiliza eficientemente el sistema lectoescritor braille o macrotipo según sea su discapacidad visual. El 73% de ellos son mujeres y el 27% hombres. El promedio de edad fue de 11 años. Un 9% eran aprendices menores de 10 años, un 55% entre 10 y 13 años, y el 36% mayor de 13 años. El 27% poseía ceguera total y el 73% baja visión. Las actividades con los aprendices se llevaron a cabo en la Escuela de Ciegos Santa Lucía de Santiago, Chile.



Figura 1: Usuarios no videntes construyendo mapas conceptuales con material concreto

En esta primera etapa se organizó una serie de actividades orientadas a observar de qué forma el aprendiz ciego o con discapacidad visual, construye y organiza los conceptos y las estrategias que utilizan frente a la elaboración de un mapa conceptual (ver figura 1). Para ello, se organizaron siete sesiones de trabajo de dos horas de duración cada una, donde se les enseñó la técnica, revisaron ejemplos, completaron y construyeron mapas conceptuales simples de manera individual y grupal, con propósitos definidos, como extraer significado de textos escritos o comunicar lo que saben de un tema. Los objetivos de las sesiones fueron: Observar la forma cómo los aprendices ciegos expresan las relaciones conceptuales que construyen en su estructura mental, identificar los tipos de relaciones que los aprendices ciegos establecen entre diferentes conceptos, identificar las estrategias que utilizan los aprendices ciegos para construir un mapa conceptual y favorecer la construcción de mapas conceptuales.

Todas las sesiones fueron registradas a través de pautas de observación apoyadas de registros fotográficos y filmaciones. Del análisis de estas sesiones se puede señalar que los aprendices ciegos relacionan conceptos utilizando proposiciones de dos o tres conceptos, evidencian dificultades para expresar el significado de conceptos como unidades de significados que son funcionales al lenguaje, establecen varias relaciones sin significado, evidencian dificultades de compresión lectora, manifiestan limitadas capacidades para sintetizar información, revelan una relación directa entre el nivel de manejo que poseen de su sistema lecto-escritor (braille o macrotipo) y las dificultades que manifiestan para construir los mapas, representan una relación directa entre el grado de discapacidad visual y las dificultades que manifiestan para construir los mapas, identifican la estructura de un mapa conceptual, requieren de apoyos externos (material concreto y facilitador) para distribuir espacialmente los conceptos, necesitan apoyos externos (facilitador) para leer y revisar sus mapas, y demandan apoyo externo (material concreto) para representar los enlaces.

A partir de estas observaciones se diseñó el software AudiodMC, buscando generar una herramienta de apoyo que sintonizara con las características de los aprendices ciegos, de forma de proveerles funcionalidades de apoyo y facilitarles el proceso de construcción de manera autónoma, como opciones para leer y revisar los mapas, y apoyo de sonido para distribuir espacialmente los conceptos.

2.2 Diseño de AudiodMC

En la segunda etapa y a partir de los resultados obtenidos durante la observación, se diseñó y desarrolló un entorno de software basado en audio que permita a este tipo de aprendices, construir mapas conceptuales. Este diseño fue basado en metodologías de diseño y desarrollo de software para no videntes (Sánchez, et al., 2004). A continuación se describe AudiodMC, su arquitectura, y sus principales componentes e interfaces.

Descripción. AudiodMC es una herramienta basada en audio que permite a usuarios con discapacidad visual crear mapas conceptuales. AudiodMC cuenta con una galería de conceptos que pueden ser incluidos por el aprendiz para construir sus mapas o incorporarlos previamente por el facilitador para apoyar la construcción de mapas conceptuales de los aprendices en actividades de aula. Una vez creada una categoría ésta puede ser reutilizada como predeterminada. Cada concepto incluido en el mapa diseñado por el usuario es caracterizado según su nivel y posición en la jerarquía mediante un indicador de audio espacializado que identifica su posición en el mapa. En los

siguientes capítulos se describe el modelo de AudiodMC, sus componentes, la interacción y sus principales interfaces.

Modelo. La figura 2 muestra la arquitectura de AudiodMC. Los componentes de este modelo son: 1. **Usuario**, que construye el mapa conceptual, 2. **Diseñador**, que corresponde al editor de mapas conceptuales y provee al usuario distintas funcionalidades para construir el mapa basado completamente en sonido, 3. **Interfaces**, conjunto de dispositivos de Entrada/Salida (el teclado, la representación gráfica y el sistema de audio) que permiten la interacción del usuario con AudiodMC, 4. **Mapas**, conjunto de nodos y relaciones que el aprendiz ciego genera con AudiodMC y que son representados en audio y, simultáneamente, en formato gráfico, y 5. **Repositorio**, contenedor de los mapas diseñados por el usuario para su posterior modificación o evaluación.

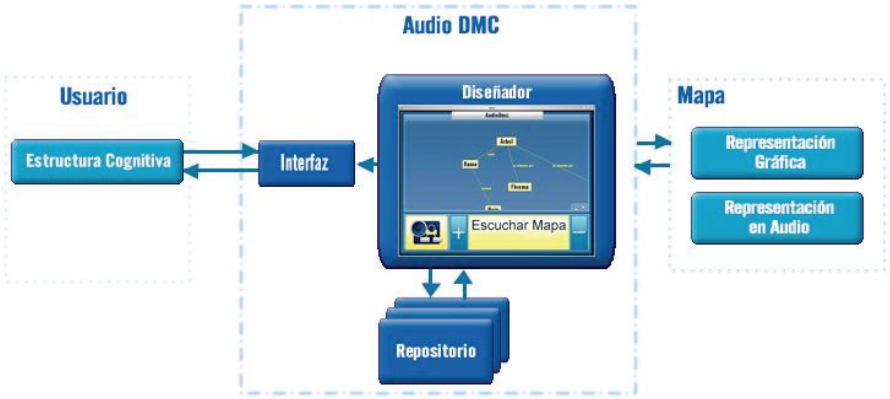


Figura 2: Modelo de AudiodMC

Componentes de AudiodMC. Los componentes de AudiodMC se presentan a través de un menú de todas las opciones que están disponibles para el usuario, estas son: 1. Crear un nuevo concepto, que permite crear un nuevo concepto escrito y asignarlo en alguna de las categorías disponibles, 2. Crear categoría, que permite crear una categoría, la cual identifica a un grupo de conceptos, 3. Crear nuevo mapa, acción que permite crear un nuevo mapa en blanco, 4. Abrir un Mapa, que permite abrir un mapa que el usuario ha diseñado y guardado previamente en el contenedor, 5. Grabar Mapa, que permite guardar el mapa diseñado. Esta información queda almacenada en el contenedor de mapas asociado a un "id" del usuario, 6. Leer Mapa, que permite escuchar los conceptos y sus enlaces, el método para esta funcionalidad es una lectura con el motor de *text-to-speech, TTS*, describiendo cada una de las proposiciones desarrolladas por el alumno, 7. Listado de conceptos, que permite revisar los conceptos previamente incluidos en el software para su uso en el mapa en desarrollo, y 8. Revisión de Mapa, que permite revisar el mapa concepto por concepto, indicando los enlaces disponibles en el orden de jerarquía del mapa.

Edición y construcción de mapas. En AudiodMC, los niveles de jerarquía y la distribución horizontal de los conceptos en el mapa son representados por distintos sonidos que están distribuidos espacialmente, con la finalidad de proveer un modelo del mapa al usuario ciego. La figura 4 muestra la distribución de estos sonidos en un ejemplo de un mapa conceptual. La jerarquización está representada por una escala de sonidos que indica cada uno de sus niveles y la distribución horizontal está representada por sonido espacializado.

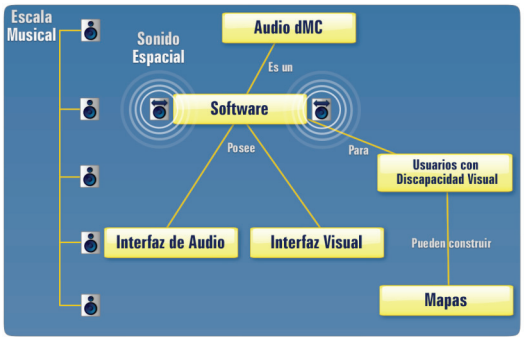


Figura 4: Representación en audio de un mapa conceptual con AudiodMC

El alumno interactúa con el software mediante el teclado, utilizando principalmente las flechas de dirección para seleccionar los elementos que provee AudioDMC. Para crear un mapa, el alumno debe primero elegir el concepto de la galería de conceptos. Esta galería incluye tanto los conceptos previamente escritos por éste, como también los conceptos escritos en actividades anteriores. Para escuchar qué conceptos puede incluir, el alumno elige por medio del teclado y la reproducción a través del *text-to-speech*, cada concepto disponible. Al momento de seleccionarlo, el concepto queda incluido en el mapa con una posición y sonido específico de la primera jerarquía disponible según el último concepto insertado previamente. Luego, mediante sonido espacializado, el alumno debe elegir en qué posición del mapa desea ubicarlo. Esta posición es modificada por el usuario mediante el uso de las flechas del teclado, cambiando el tono (verticalidad) o la posición de izquierda/derecha (horizontalidad). Este mismo proceso se repite cada vez que se inserta un concepto. Además, durante el proceso de creación de un mapa conceptual, AudioDMC construye un mapa gráfico que sirve de ayuda a los usuarios con visión residual, para identificar la posición de los conceptos y las relaciones que se han desarrollado con anterioridad.

Para modificar la posición de los conceptos, borrarlos o escuchar sus enlaces con otros conceptos, existen dos métodos que el usuario puede elegir: 1. **Revisión concepto a concepto**, en el cual se dispone de un submenú asociado que permite ejecutar acciones como: crear proposición, escuchar concepto, eliminar concepto y revisar enlaces del concepto seleccionado. La navegación por el mapa a través de este método permite escuchar las proposiciones que se han desarrollado, al mismo tiempo que se proporciona feedback auditivo de la posición en el mapa, lo que permite tener un control de los procesos de edición y construcción de éste, 2. **Revisión por proposiciones asignadas**, esta revisión permite revisar el mapa a partir de las relaciones que existen entre los conceptos. Las proposiciones se crean mediante grabaciones que el usuario debe hacer con el micrófono o bien las escribe a través del teclado.

Interfaces. Las interfaces gráficas desarrolladas utilizan un alto contraste de colores para que puedan ser utilizadas por usuarios con baja visión (Rinden, 1999).



Figura 5: Pantalla de principal de AudioDMC

La figura 5 presenta la interfaz principal de AudiodMC, la cual consta de: 1. **Area de trabajo**, lugar donde son insertados los conceptos y las proposiciones del aprendiz, 2. **Menú principal**, que permite la visualización del estado actual de la conducta del aprendiz, 3. **Area de interacción**, que permite la interacción del aprendiz a través del teclado con AudiodMC y muestra los textos que son reproducidos por el *text-to-speech*, palabra por palabra.

2.3 Evaluación preliminar de usabilidad de interfaces

En la tercera etapa, el software fue sometido a una evaluación preliminar de usabilidad de interfaces para mejorar la pertinencia de la aplicación al contexto de los usuarios con discapacidad visual (ver figura 6). Para esta evaluación de usabilidad se realizó una observación basada en tareas que permitió identificar algunos problemas de interacción del usuario con AudiodMC. La siguiente tabla muestra las interfaces evaluadas y las tareas a desarrollar asociadas a la evaluación de cada una de ellas.

Componente de interfaz	*Tarea*
Interfaz de entrada	• Abrir la aplicación • Ingresar nombre
Menú principal	• Revisar los componentes del menú principal • Reconocer cada uno de los elementos y preguntar su significado
Herramienta para crear un concepto	• Ingresar a componente para crear un nuevo concepto • Seleccionar la categoría para un concepto nuevo
Inserción de un concepto en el área de diseño de un mapa conceptual	• Seleccionar el concepto a insertar • Ubicar concepto según pistas sonoras
Efectividad del sonido de ubicación espacial (horizontal)	• Insertar un concepto después de haber ingresado otro concepto previamente • Desplazar el concepto insertado en una jerarquía determinada
Efectividad de sonido de jerarquización de conceptos	• Insertar un concepto después de haber ingresado otro concepto previamente • Desplazar el concepto insertado a través de los niveles de jerarquía disponibles
Proceso de revisión de conceptos en el mapa conceptual	• Entrar al componente del menú principal de revisión de mapa • Revisar los conceptos ingresados
Proceso de grabación de enlaces	• Revisar el mapa • Ingresar al submenú de un concepto • Crear enlace y grabar el sonido

Tabla 1: Tareas de la evaluación de usabilidad de interfaces de AudiodMC

Estas tareas fueron desarrolladas por 12 aprendices, 10 ciegos legales y 2 ciegos totales, de entre 8 y 15 años, 8 mujeres y 4 varones, que durante una sesión de 40 minutos debieron realizar las tareas solicitadas y posteriormente, completar una escala Likert leída por el evaluador en la que frente a cada afirmación de los componentes de la interfaz debían señalar si la consideraban muy buena, buena, neutra, deficiente o muy deficiente.

Los 12 participantes evaluaron como bueno o muy bueno todos los componentes de la interfaz, a excepción del componente efectividad de sonido de jerarquización de conceptos, en el que 8 aprendices lo evaluaron como deficiente o muy deficiente, realizando además sugerencias cruciales para un entendimiento y control del uso de los elementos de la interfaz de AudiodMC, como por ejemplo, hacer que la voz sea más placentera, que el sonido avance más lento, que las diferencias entre los sonidos usados en la escala sean más marcadas para favorecer la referencia de la posición de los conceptos en los diferentes niveles de la jerarquía.




Figura 6: Usuarios no videntes construyendo mapas conceptuales con AudiodMC

2. Discusión

Durante el proceso de diseño de AudiodMC se pudo observar que, inicialmente, la mayoría de los aprendices ciegos desconocía la técnica de mapas conceptuales y se manifestaron incompetentes para abordar las actividades. Sin embargo, al introducirlos en el tema rápidamente se manifestaron motivados y destacó la concentración con que enfrentaron las actividades propuestas.

Los factores que afectaron la realización de las diferentes actividades fueron: dificultades de comprensión lectora, limitado número de conceptos a los cuales atribuyen significados profundos, escaso desarrollo de habilidades de atención y retención de información.

Al principio la estructura de los mapas que construyeron los aprendices fue fundamentalmente sobre la base de conceptos superpuestos o muy cercanos unos con otros, sin conectores ni palabras enlaces. Progresivamente y con la incorporación de referencias espaciales externas como las indicaciones del facilitador o material concreto, lograron construir mapas donde se aprecia una diferenciación y jerarquización de conceptos. Los aprendices ciegos totales evidenciaron mayores dificultades a la hora de construir un mapa que aquellos que poseen baja visión.

Creemos importante destacar que este trabajo de observación nos ha permitido identificar claramente el fenómeno del verbalismo que desarrollan los aprendices ciegos, ya que en su vida diaria utilizan muchos conceptos que no poseen significado para ellos y que aún cuando su uso les resulta muy importante para desenvolverse socialmente, no logran establecer conexión entre estos conceptos y otros relacionados. Como proyección de este estudio planificamos utilizar los mapas conceptuales como una estrategia para enriquecer el significado de estos conceptos, apoyando la construcción de significados que carecen de referentes visuales a través de su relación con otros conceptos por medio de los mapas conceptuales.

Uno de los resultados más importantes de la etapa de diseño de software es que el diseño centrado en el usuario de un software de estas características, mejora sustancialmente la interacción del usuario no vidente con el software resultante. Esto se debe a que esta metodología involucra al usuario en el proceso de diseño, considerando sus necesidades, intereses y formas de interacción natural e intuitiva. En particular, AudiodMC se implementó basado en esta metodología, realizando rediseños iterativos para acercar su funcionalidad a la manera más apropiada al modelo mental de estos usuarios, basándose en cómo el aprendiz no vidente o con déficit visual, construye y organiza los conceptos y qué estrategias utiliza en la construcción de un mapa conceptual.

La etapa de evaluación preliminar de usabilidad de las interfaces de AudiodMC fue crucial para el diseño de un software que se adecue al modelo mental de un usuario no vidente. Los comentarios de los usuarios giraron principalmente entorno a la calidad del sonido. Esto nos demuestra que una correcta metodología de diseño y desarrollo minimiza los errores de interacción entre el usuario y el software.

Los siguientes pasos a seguir en esta investigación consistirán en la evaluación del uso de AudiodMC como una herramienta que permita a usuarios con discapacidad visual, utilizarla en contextos de aprendizaje de aula o en el hogar. Esto nos ayudará a definir *guidelines* más específicos para el proceso de diseño de interfaces para no videntes y alinear más aún nuestros objetivos con las formas de interacción de usuarios con discapacidad visual. De esta manera, podremos definir un nicho de uso de los mapas conceptuales que puede constituirse en una valiosa ayuda para la construcción de significados por parte de aprendices ciegos.

Referencias

Alderete, O. (1988). Lectura braille y procesamiento de la información táctil. Madrid, España.

Rivero, R. (1986). El desarrollo cognitivo en ciegos según las teorías piagetanas y del procesamiento de la visual información 1982-83. Madrid, España

Alderete, O. (1988). La influencia del medio escolar en el desarrollo cognitivo del niño ciego según la teoría piagetana y del procesamiento de la información. 1984-85. Madrid, España

Ausbel, D., Novak, J. & Hanesian, H. (1978). Educational psychology, a cognitive view. 2nd Edition. New York: Holt, Rinejhart, and Windston.

Cañas, A. Hill, G. Carff, R. Suri, N. Lott, J. Gómez, G. Eskridge, T. Arroyo, M. Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (1), pp. 125-133.

González, F. & Novak, J. (1996). Aprendizaje Significativo, Técnicas y Aplicaciones. Madrid: Ediciones Pedagógicas

Luckie, D. Harrison, S. Ebert-Ma, D. (2004). Introduction to C-Tools: Concept Mapping Tools for Online Learning. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (2), pp. 261-264.

Moreira, M. (1998). Mapas Conceptuales y Aprendizaje Significativo. Revista Galaíco Portuguesa de Socio Pedagogía y Socio Lingüística, N°23. Pontevedra/Galicia, España y Braga, Portugal

Novak, J.D. (2003). The Promise of New Ideas and New Technology for Improving Teaching and Learning. Journal of Cell Biology Education, 2(Summer): 122-132

Novak, J. & Gowin, B. (1984). Learning How to Learn. New York: Cambridge Press.

Novak, J. (1998). Learning, Creating and Using Knowledge, Concept Maps as Facilitative Tools in Schools and Corporations. New York: Lawrence, Erlbaum Associate, Inc.

Novak, J. & Cañas, A. (2004). Building on new constructivist ideas and CmapTools to create a new model for education. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (1) pp. 469-476

Ramos, M. (2004). El Mapa Conceptual, Estrategia Didáctica Significativa. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (2), pp. 301-304

Rigden, C. (1999). The eye of the beholder: Designing for colour-blind users. British Telecommunications Engineering, 17. Retrieved Feb. 6, 2004, from http://more.btexact.com/ces/colours/colours.pdf.

Rodríguez, M. (2004). La teoría de Aprendizaje Significativo. In. A. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (1), pp. 535-544

Rueda,U. Larrañaga, M. Arruarte, A. Elorriaga, J. (2004). Applications of a Concept Mapping Tool. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st Internacional Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (1), pp. 545-553.

Ruiz, F. (1997). El niño ciego en la escuela. Iniciación al sistema braille. Sevilla: Dirección General de Formación Profesional y Solidaridad en la Educación. Consejería de Educación y Ciencia. Junta de Andalucía.

Sánchez, J. Alarcón, P. (2004). Diseñador de Mapas Conceptuales: Una Herramienta Implementada con y para el Usuario Final. In. A. Cañas, J. D. Novak & F. M. Gonzalez (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (1), pp. 563-570

Sánchez, J. Alarcón, P. (2005) Construcción de Conocimiento con Editores de Mapas Conceptuales. En Sánchez, J. (editor) Memorias X Taller Internacional de Software Educativo, TISE 2005, pp. 202-211, Santiago 5-6 y 7 de Diciembre, 2005.

Sánchez, J., Baloian, N., Flores H. (2004). A methodology for developing audio-based interactive environments for learners with visual disabilities. Proceedings of ED-MEDIA 2004. June 21-26, 2004. Lugano, Switzerland, pp. 540-545.

Sánchez, J., Flores, H. (2004). Memory enhancement through audio. ACM SIGACCESS Accessibility and Computing archive Issue 77-78, pp. 24-31, Sept. 2003-Jan. 2004

Sánchez, J., Lumbreras, M (1999). Virtual Environment Interaction through 3D Audio by Blind Children. Journal of Cyberpsychology and Behavior, CP&B 2(2), pp. 101-111.

Sánchez, J., Sáenz, M. (2005). 3D Sound Interactive Environments for Blind Children Problem Solving Skills. Journal Behaviour & Information Technology, BIT, Vol. 25, No. 4, July August 2006, 367-378.

Tascón, C. (2004). La Potenciación de Aprendizajes en un entorno T.I.C.: Los Mapas Conceptuales como Instrumento Cognitivo y Herramientas de Aprendizaje Visual. In. A. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Septiembre 14-17, 2004, (2), pp. 347-350.

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DYNAMIC VISUALIZATION OF CONCEPT MAPS: FIVE DIFFERENT MODELS

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Abstract. The importance of the conceptual maps' development and of the software instruments that set them up in phase of composition and utilization, in the context of e-learning, derives evidently from their connection with the thematic of the knowledge's onthologic structuring: the representation of the elements and relations that constitute an onthological frame has to be founded on the graphs' theory, linking the elements to the nodes and the relations to arcs, in relation to the rules defined from J.Novak (1984).. The conceptual maps, however, are not configurable simply as products of the concept's evolution of contents' indexing, from which they differ structurally because they are not limited to the representation only of the hierarchical relations, since their role is dilated from the knowledge's organizational function to the transmissional function, assuming a specific task into the explicitness of the cognitive context that involves an intrinsic value about didactics, a various and ulterior task regarding the navigation support. In the relationship between knowledge's organized aggregation and representation, moreover, it's evident the requirement to automate the reconstruction of conceptual maps, using algorithmic models, owing to simplify the modalities of structural modification through a direct connection with information integrated in a database management system, and in the meantime to be able to use multiple shapes of representation and observation corners.

1 Introduction

CARID's research (Center of Athenaeum for Research, Didactic Innovation and Distance Instruction, University of Ferrara) has produced five models of automatic composition of conceptual maps, some of them rebuilding from each of the concepts that compose the cognitive contexts, other rebuilding from a predefined or randomized distribution of the concepts in the documental space, some characterized from a bidimensional graphic, other three-dimensional ones susceptible, as virtual objects, of rotations and variations of visualization corner. These models, working on the web, capture the data from a DBMS and compose images of maps visible in the browser and sensitive to the input events; therefore these maps can support navigation's functions or didactic interaction, both in SVG format, vectorial graphic standard deriving from XML and produced from Consortium W3C, and inside a Java applet. In the context of the formative processes managed from CARID, their use is connected particularly with the functionalities of structured forum and organized aggregation of documents and Learning Objects that support the didactic activity.

Inside e-learning environments, knowledge's representation of didactic domains using concept maps is an effective way to support context's navigation and documents' organisation: concept maps assume essentially the previous role of books' indexes, a role of domain's structural representation and guide to knowledge research and discovery for students. Therefore, the use of specific concept mapping tools, such as CmapTools (Cañas & Lott, 2003, Cañas et al. 2004), allows to link documents to the map's nodes, which become repositories of knowledge, and to point out relations (and to trace didactic paths) using map's arcs. A particular emphasis on the role of map's arcs proceed from the development of domains' ontologies and their representation: in order to explain and deepen a context's structure, relations' tissue becomes gradually more important than nodes' definition, and concept maps' potentiality becomes significantly more effective than other knowledge's representation methods or instruments, which don't define and don't label the arcs-relations, such as mind maps or indexes.

But the evolution toward domain's ontologic representation and structural deepening converts concept maps from enhanced and empowered indexes, which support structures, to documents, which can support both structures and contents: a concept map can be not only a well-organised structure which indexes repositories of documents, or a navigation guide among the context's arguments, but also a real knowledge support, a real learning object.

Carid experience demonstrates that the use of conceptual maps is placed in middle position between e-learning and knowledge management, it is indeed the conjunction ring, since it allows not only knowledge's structured aggregation, but also negotiation of meaning and relations between the customers of the map: in other words, the conceptual map is transformed from shared structure to shared document, that is object of knowledge, and it is shaped as reference instrument both for the didactic interaction and for the explicitness of tacit knowledge.

2 Conceptual maps' representation through dynamic rebuilding

The role of the conceptual maps in the e-learning, and in a more generalized manner in the knowledge management, is not limited to the macrostructure's representation of cognitive contexts (that is to the support, in more evoluted shape, of the same function that previously was covered from the hierarchical index), but extends its role in other directions, and specifically:

1. the representation of large and complex structures (hundreds or thousands of nodes), that is characterized from many non-hierarchical interconnections;
2. the enrichment and the progressive deepening of the structures, and the negotiation of meaning, during the collaborative activity of the interlocutors of e-learning process, activity of knowledge's organized aggregation, from a constructivist point of view;
3. the unification, in the context of the same map, of both the aspects of context's representation and knowledge's explicitness, that is the use of the map like instrument both of structuring and of writing the contents.

In these multiple functions, an important improvement in the use of the conceptual maps comes from their transformation from dynamic to static documents, that is from documents produced through direct participation of the authors, facilitated from generic or specific instruments of graphic editing, to reconstructed documents capturing, from a database or a structured document, the information connected to the concepts and the relations to be represented, and reconstructing their graphical aspect using software procedures founded on particular algorithms.

The dynamisation of the concept map implies also the polymorphism, that is the transformation from single document, as a static one, to set of potential documents, whose differentiation derives from the options permitted from the software procedures, which for example:

- the possibility to implement in the algorithm of reconstruction the distribution's randomisation of the nodes, recreating to each request a different map's image;
- the possibility to reconstruct the map with rigorous procedures of a category that we can define "proximal development", i.e. characterized from the successive placement of the nodes in function of the position of the first one, procedures that always regenerate, starting from a specific node, the same design, but that generate various map's images based on the choice of the first node to place;
- the possibility to reconstruct the map according to "gravitational development" procedures, in which the first nodes' collocation, randomized or collected in document's center (nearly a simulation of "big bang"), balances and progressively stabilizes depending on the characteristics of connections that tie them (this modality obviously need the definition, inside the database, of intensity of every relation between two concepts);
- the possibility to implement, in the map visualization's instrument, functionalities of bidimensional or three-dimensional animation (mouse-driven animation), which permit its vision from different observation corners;
- the possibility to use in ergonomic way also maps extremely great for number of nodes and arcs, using functionalities as zoom or virtual magnifying lens;
- even the use of the background as third graphical element of the conceptual map, as not neutral but being able to support information using color or pattern's variations (Carid is still experimenting the use of background color in order to define intrinsic characters of the map, such as the interconnection's level of content's elements and the maps' tendency to be aleatory or scale-free, or extrinsic ones, such as separation of the map in zones based on contextualisation's concepts parameters).

In order to realize the potentialities of conceptual maps' dynamics reconstruction, the research carried out from Carid has originated the following models of map's representation:

1. “proximal development in concentric circles” graph
2. “proximal development in hierarchical circles” graph
3. “proximal development three-dimensional rotable conic structure” graph
4. “gravitational development three-dimensional initial random distribution rotable structure” graph
5. “gravitational development three-dimensional big-bang rebuilding rotable structure” graph

2.1 "Proximal development in concentric circles" graph

A procedure of rigorous construction of graph's figure is founded on the concentric circles, that permit nodes' distribution depending on their distance from an original node. The choice of the "root" node (in order to use a typical terminology of the tree structure) is the obliged step for this rigorous graphical reconstruction.

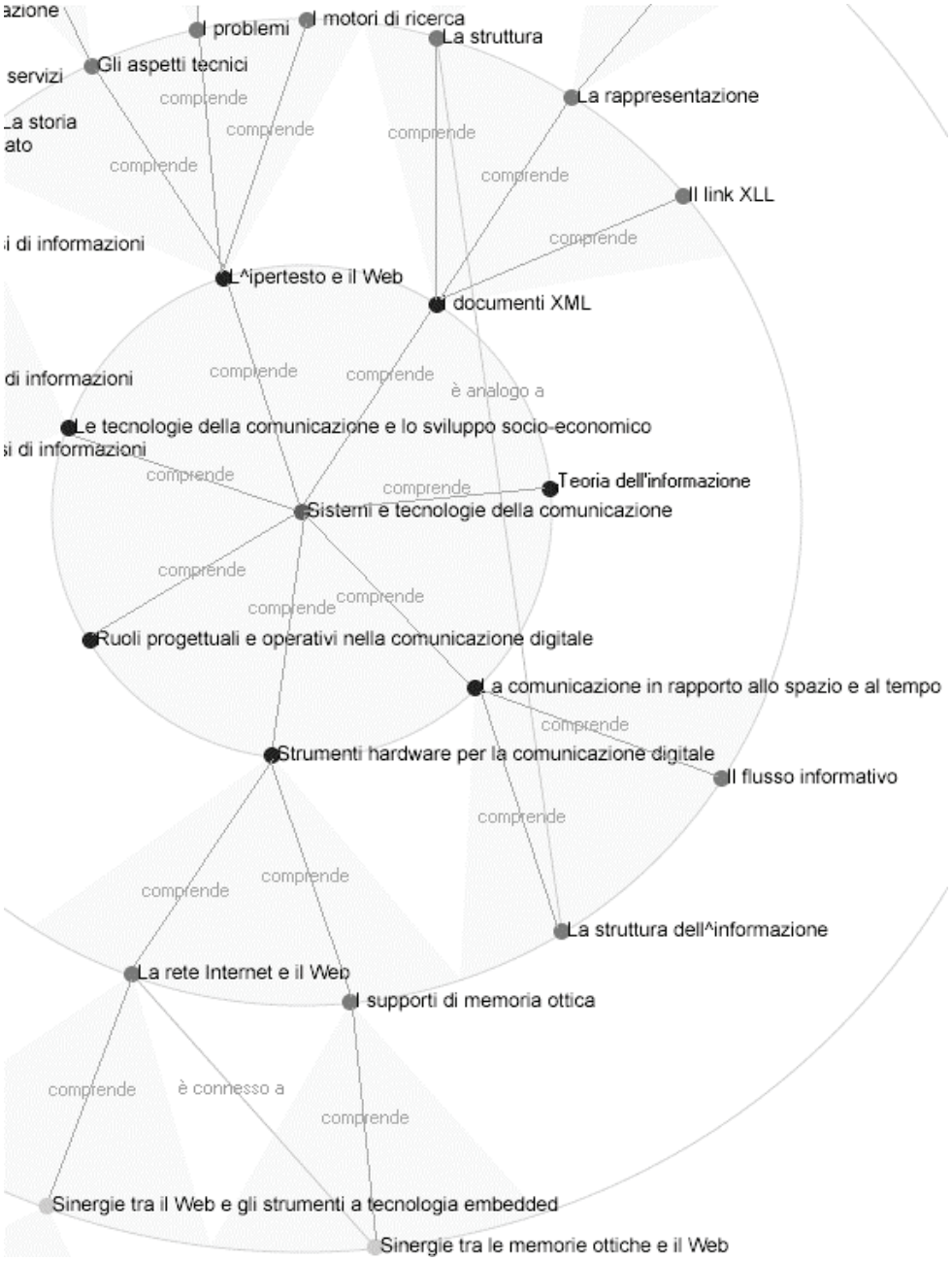


Figure 1. "proximal development in concentric circles" graph

Determined the root node, the procedure continues with the distribution of the nodes connected on a circumference whose center is the same root node, afterwards reiterates the algorithm distributing, on a circumference concentric to the previous one, the nodes connected to the nodes situated on the first circumference, so that the links are dilated in radial matter (obviously, the nodes connected to a node situated north of the first

circumference will approximately occupy the field between the northeast and the north-west section of the second circumference).

The procedure tends to expand then itself in relation to the number of concentric circles necessary to the representation of all the nodes: the detailed vision of this map needs therefore the functionalities of scrolling and paneling.

This method, that can also be used for the representation of a tree structure, offers a possibility that the index does not permit: in the case in which one of the nodes that would be placed on circumference x, owing to its connection to one of the nodes of the x-1, are already present in the circumference y, this node is not placed on x, but the connection between the two nodes, placed on the circumferences x-1 and y, is traced. In this way all the connections can be evidenced, moreover the concentric circumferences show the connection's distance (degree), as number of intermediate nodes, between each node and the root node, at least the procedure is rigorous, automatizable, and reproduceable starting from whichever node: it is possible therefore to generate as many various graphs as are the nodes, and this is a way in order to qualitatively improve the information's expression on the structure of a content.

The dynamic model realized by Carid has been developed in Java environment: the map is produced from a servlet that reconstructs an image in the structured markup language SVG, supporting vector graphic.

2.2 "Proximal development in hierarchical circles" graph

A second rigorous procedure for graphs' reconstruction, which supports an effective communication, is based on the reiteration of the context's scheme of each node.

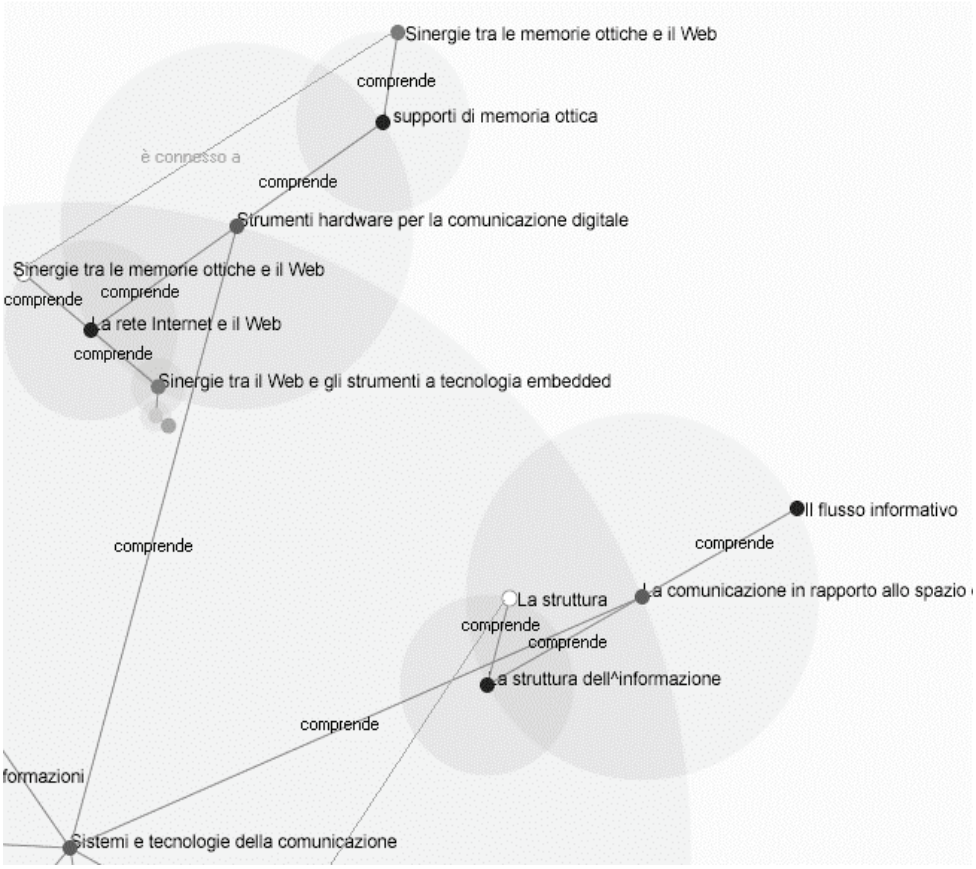


Figure 2. "Proximal development in hierarchical circles" graph

The algorithm starts, analogous to the “concentric circles” procedure, from a root node around which locates, on a circumference, the nodes relative to arguments connected to the root, linking them to this using radial segments, and continues considering each node of the circumference as central node of its system, and constructing round it a second circumference, of smaller diameter than first, locating the connected nodes and tracing the radial segments.

Unlike the previous scheme (but both the options are possible in both the schemes), when a B node already present in the structure appears, among the nodes connected to the node A (that is when a link of not hierarchical type between two nodes is evidenced), algorithm doesn't trace a segment between A and B, but a second B node is designed on the circumference round to A, evidencing its nature of "alias" regarding the first B with a graphical characteristic, and connecting it to this: in this way, the transversal links connect always two different positions referred to the same argument, contributing to clarify the relations' structure.

In opposition to the concentric circles graph, the diameter of the hierarchical circles graph decreases at the increasing of the distance from the root node, consequently, this model does not tend to expand itself when the number of nodes and arcs increases, unlike the previous one, but it tends to increase the concentration of the nodes in the surface unit: therefore the detailed vision of this map is based on the zoom's functionality.

This representation permits to distinguish from the topic's concept, represented by the node, the area's concept, represented by the gray circle, that encircles the node, and which shows the child-nodes on its circumference: the area can be used like representation of a graph's part, composed from a node and its descendants (its sons, sons of sons etc), and this potentiality reveals its utility in the context of particular activities (for example, in e-learning, the vision of all the contributions, or all the participations, relative to a topic and to the group of topics that derive from that).

Also this dynamic model realized from Carid has been developed in Java environment, and the image is reconstructed in language SVG.

2.3 “Proximal development three-dimensional rotable conic structure” graph

The algorithmic reconstruction of the conic graph is essentially an intermediate modality between the reconstructions of “hierarchical circles” and “concentric circles” graphs: subsequently to the development of the first circumference around the central node and to the location of the nodes connected to this, the image increases through the calculation of the circumferences of child-nodes' expansion, and the location of the derived nodes in the external semi-circumferences. The fundamental aspect of this reconstruction is the introduction of the third dimension: to each level of distance from the root node the depth of the image increases of a fixed largeness, generating the design of a conic shape.

This distribution implies, in the case of maps composed by many nodes and many relations, an increase of the complexity so fast as to get the image quickly unreadable, because of the superimpositions of nodes, arcs and labels. But the insertion of the tridimensionalisation is motivated from a functional issue, necessarily connected to this graphical model, that exceeds and eliminates the problem of readability: conic graph's vision has to be supported, using adapted software instruments, by the possibility to control the optical corner, that is to animate rotation in all the directions with mouse-driven events.

The structuring of the image of this map is realized inside a Java applet, optimal technology in order to permit the complex rendering software of the conic graph. In the sphere of usability, a similar instrument considerably expands the expressive potentialities of the conceptual map, conferring it also a ludic value, connected to the three-dimensional animation, that catalyzes the attention of the customers not only on the relations and topics' net that the map composes, but also on the shape of the same map. This consideration requests a deeper analysis, which in this paper we just point out, because the shape of a complex concept map can be interpreted like ulterior information relative to the cognitive context: about it, it is opportune to mention the theory of the scale-free nets (Barabasi, 2004), that analyzes the incidence between elements and relations on a net.

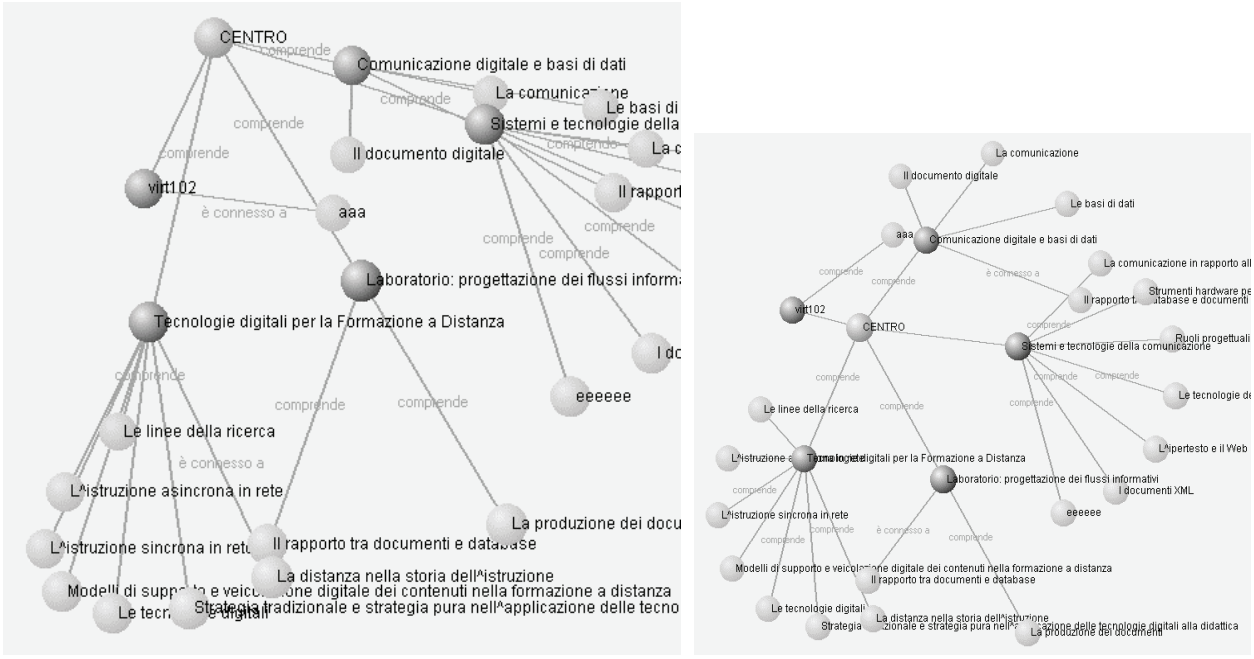


Figure 3-4. "Proximal development three-dimensional rotable conic structure" graph, and the same graph after a rotation

2.4 "Gravitational development three-dimensional initial random distribution rotable structure" graph

The structure of the conceptual maps to proximal development repeats constant outlines (concentric circles, hierarchical circles, cone) that tend to underline the net of relations according to a vision that confers to a single node the source's role, or root: the fact that this node is, in the previous models, interchanging with all the others, renders the maps polymorphic but it doesn't overcome the inability to prescind from "one" origin.

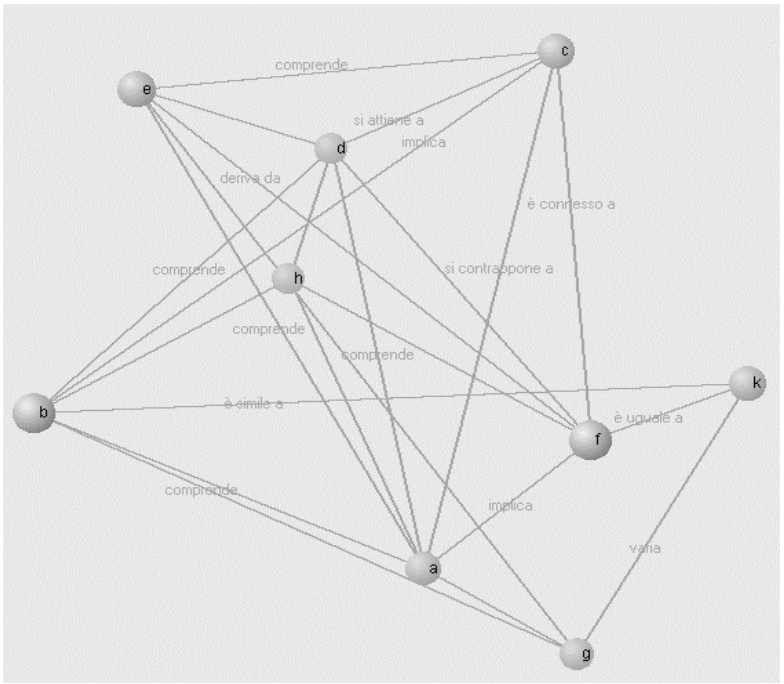


Figure 5. "Gravitational development three-dimensional initial random distribution rotable structure" graph

It's not simple to imagine an automatic distribution of the concept map's nodes that resolves the problem of the proximal development and the nodes' location in function of a first one "pivot", but this difficulty can effectively be overcome if a degree of intensity, or attraction, between the nodes connected by these relations, is associated to the same relations, using a value, a couple of values or with other requests of quantitative or qualitative character.

Starting from this consideration, and adding to the informative base for the dynamics reconstruction of the conceptual maps an indicative value, for every single relation, of the degree of attraction between two concepts, Carid's research has produced a software model, always in technology Java-applet, that distributes originally, in the document's space, the nodes according to an accidental disposition, and subsequently animates the movement up to an acceptable configuration.

The animation considers tendential distance between the connected nodes, calculated on the basis of attraction degree, and, using an algorithm based on multithreading, simulates an individual nodes' behavior, that move themselves contemporaly in the document's space, as function of resultant's calculation of a system of forces derived by the relations that each node has with the nodes connected to itself: sinthetically, the algorithm simulates the application of a species of "gravitation" in the space occupied by the nodes.

The activity of the algorithmic threads that move the nodes finishes when the outline has got up to an equilibrium degree, judged sufficient and strongly improveable, that is when the differences between the distances among the connected nodes and the tendential reference's distances are inside a acceptability range.

The documents' space should be three-dimensionable, in order to permit a fast achievement of this point of equilibrium and a satisfying outcome of the algorithm's application, as for the cone maps: applying therefore the same functionality of a mouse-event interception, also the “gravitational development” map is rotable.

In this map the division between the maps and the indices is concluded, because each reference to a possible hierarchy between the node-concepts disappears, and the characteristic of polymorphism get extreme, in function of the initial randomized nodes' disposition: it derives, however, the impossibility to reconstruct the identical configuration as a result of the repetition of the algorithmic procedure on the same base of data.

2.5 “Gravitational development three-dimensional big-bang rebuilding rotable structure” graph

This model of map reconstruction, still in phase of development, does not differ, as far as final kind of representation and algorithm of gravitational equilibrium search, from the previous one, but on one side it reduces the polymorphic potentialities, on the other side it overcomes the impossibility of reconstruction's precise repetition, bypassing the randomisation's request of initial distribution of nodes.

The nodes, in this model, are originally placed in the center of the document's space, and the multithreaded algorithm, which reallocates each node in function of the resultant of the attractions with the connected nodes, simulates visually, in this case, the effect of the initial "big bang" of the universe. The distribution of the nodes to the achievement of the equilibrium point, because not subordinated to the casuality of initial location, is precisely rebuildable, repeating the algorithmic procedure, in the same shape.

3 Conclusions

The aspect of greater interest in the research inherent to the dynamic concept maps' reconstruction is represented from the possibility to operate a choice of the composition model, and consequently of the used algorithm, in function of the peculiarity of the cognitive sphere and the use's context of the realized communication's instrument.

The representation of a social network, characterized from a high number of nodes and arcs and presumably from a structure of "scale free" type (Barabasi, 1999), is better expressed therefore from a three-dimensional structure and gravitational development map, that does not privilege a “root” node and can offer uncountable angles of visualization and multiple levels of image's magnifying.

On the contrary, the representation of an onthological sphere not particularly complex, and finalized to support the exploration of a disciplinary cognitive context in a didactic environment, as for example a course distributed in e-learning modality, will find a better graphical release using a proximal development for concentric circles or hierarchical circles map, simpler and immediate to use even for users not enough bent to using these instruments.

But beyond these methodological and technological observations on the use of the concept maps, it is necessary also to emphasize the importance of their dynamic reconstruction for the representation of contexts that, even if characterized by imposing masses of data and by frequent updates, need a multidimensional, graphical representation, observable to various detail levels and constantly refreshable in real time: the use of the concept map like image that transmit contents is considerably permeating the communication, and therefore the culture, of the actual age, and is extending its use in extremely diversified sectors.

It derives, at least, the necessity of progressively improve and to share the modalities of concept maps' dynamic reconstruction from the point of view of the progressive differentiation of a kind of polymorphic, specific writing for digital technologies and the web, that, clearly separating the aspect of information conservation from the aspect of its representation, can be shaped in function of the expressed contents' characteristics and the users.

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References

Barabasi, A. L. (2004). Link La scienza delle reti. Torino: Einafudi

Cañas, A. J., Hill, G., & Lott, J. (2003). Support for constructing knowledge models in CmapTools (Technical Report IHMC CmapTools 2003-02). Pensacola, Florida: Institute of Human and Machine Cognition.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Tamayo, M. F. A. (2004). El mapa conceptual: un texto a interpretar. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Kremer, R. (1994). Concept Mapping: Informal to Formal. In Tepfenhart, W., Dick, J. & Sowa, J. (Eds.), Proceedings of the Third International Conference on Conceptual Structures, Knowledge Acquisition Using Conceptual Graphs Theory Workshop. University of Maryland College Park, MD., Aug 19, 1994. pp. 152-167.

Tillman, W., & Wissmann, J. (2004). Dynamick concept maps for Music In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Pedroni, M. (2005). Knowledge mapping attraverso la ricostruzione automatica di mappe concettuali dinamiche. Paper presented at the 10th Knowledge Management Forum. Siena, Italy.

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EFFECTS OF CONSTRUCTING CONCEPT MAPS ON THE QUALITY OF WEB-SEARCHED INFORMATION AND SUBSEQUENT INQUIRY PROJECTS

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Abstract. The study investigated whether the use of concept mapping as a preparatory stage for identifying relevant information on a given research subject on the web, improves search results. In addition we analyzed the effects of the search process on the quality of inquiry projects, prepared by sixth graders. 78 students from three classes participated in the study. They were assigned to 27 small teams (about three students in a team) for the purpose of preparing inquiry projects. The teams, balanced across classes, were randomly assigned to three intervention groups. One group was instructed in preparing concept maps for the purpose of searching the web to find relevant documents. The second group was instructed in preparing lists for the search purpose. The third, control, was instructed in identifying main ideas of texts. All the groups searched on the web and found a similar amount of documents. The map and the list groups found better quality documents than the control. An advantage for the map group over the list and the control was found in the inquiry projects. The map teams were superior over the list teams in integrating relevant concepts in their projects and producing more coherent projects as a result of their engagement in the mapping activity.

1 Theoretical background

Information retrieval is a process of searching for and identifying specific information amongst a large quantity of other items (Bates, 1987). In activating an information retrieval system, problem-solving and decision-making processes take place, based on negotiations between the searcher and the retrieval system (Borgman, 1987). The act of searching is a result of a matching between the need for information and its wording via a query. While information search technologies have improved significantly in the past decade, and information retrieval is faster, there is still not enough knowledge on aiding the development of web search skills. Therefore, there is a need for cognitive tools that assist learners in efficient information search on the web. One such tool is the concept map.

Concept maps are tools for organizing and representing knowledge (Novak, 2004). They are one of several types of graphic organizers (others are lists and tables, charts and illustrations), that supports the learner in organizing knowledge from self or external sources, such as texts or other materials (Jonassen, 1998). Concept mapping can be used at various stages of inquiry. They can be used during the preparatory stages of planning, or for searching information, by preparing a graphical outline, based on the learners' prior knowledge, of the required information in the web (Payton, 1999). Concept mapping can be also used in later stages of learning the retrieved documents, and during writing up the final inquiry report (Kozminsky & Nathan, in preparation). In this study, we'll explore concept maps constructed by students based on their personal knowledge as a preparation for information search on the web and for inquiry learning. Following the search, the concept maps are updated, using the new relevant information found on the web, and serve as a further search input or for preparing the learning assignments, such as preparing an inquiry project in the present study.

Concept mapping can be constructed individually or in groups. Researchers (Vilberg, 1996; Roth & Roychoudhury, 1993) recommend a cooperative framework as the preferred mode for using concept mapping. This study investigated the efficiency of search, and subsequently, the quality of inquiry projects of students who learned in a cooperative format.

In instructing students to search information in this study, we applied our method of Text Concept Mapping (Nathan & Kozminsky, 2004). Text Concept Mapping is an external graphic representation of the main content ideas of a learnt text and its rhetorical organization. Content and structural information nodes are graphically distinct by using different spatial forms and/or colors (see example map in Figure 1). This type of concept mapping assists in improving text comprehension and can be constructed either prior to reading the text, during the reading, or after reading is completed, depending upon the objectives of the learning process (Nathan, 2002).

Our hypotheses were that searching information on the web using a constructed concept map prior to preparing the inquiry project, is more efficient than searching for information using only a constructed list of concepts, which is less restrictive than maps (Collins & Ferguson, 1993), and more efficient than locating information on the web with no prior graphic tool preparation (Carnot, Dunn & Canãs, 2000). We expected also to find significant differences between the qualities of the inquiry projects, with an advantage for the concept map group.

2 Method

85 students from three sixth grade classes at an elementary school in Israel participated in the study. The research was conducted in two stages, during a total of 17 bi-weekly 45 minutes lessons:

(1) The training stage: First, background data were gathered and a reading comprehension test (Kozminsky, 1992) was administered (one lesson). In the second meeting, a questionnaire to obtain data about prior knowledge of using computers and the web was given, and then, a list of nine subjects for research projects was produced together with the participants (one lesson). In the third meeting, the students received instruction about preparing an inquiry project (one lesson), and after this meeting the students in each of the three classes were randomly assigned into one of three study groups: a *concept map* group, a *list* group and *control* group. The students were pre-assigned to 27 teams (nine teams in each group, about three students in a team), each of which carried out an inquiry on one of the nine subjects (e.g., disease, terrorism; fashion). In the fourth meeting all the groups received instruction and practice, relevant to their study conditions (one lesson): learning to construct concept maps or lists of concepts about the study subject, or general instruction on how to identify central ideas of a topic based on texts (control group). During the fifth – seventh meetings, all the groups received general instruction about how to search information on the web (three lessons), as well, using standard search engines (i.e. Google, Yahoo, etc.).

(2) The study stage: The participants in the concept map group constructed concept maps based on their personal knowledge about the chosen research question, and they then used the map to search for information on the web (e.g., Figure 1). After the search process was completed, the participants updated their concept maps with the new and relevant information (e.g., Figure 1).

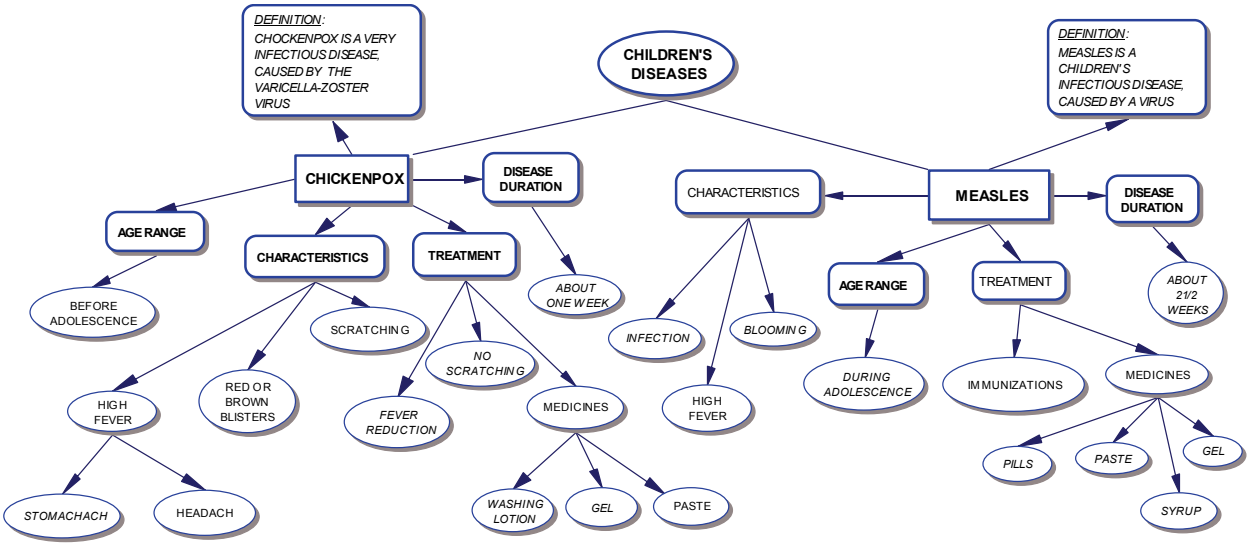


Figure 1: An example concept map of a team (translated) based on the inquiry question: What is the difference between chickenpox and measles? (The team's inquiry theme was "Diseases"). The map was constructed by the team before the search and updated following the search (*the concepts in Italics*). The different types of nodes were originally differentiated by also applying different colors. Here the entire differentiation is represented through different node shapes.

Participants in the list group drafted a list of concepts based on the research question, and used it to search information on the web (e.g., Figure 2). At the end of the search process, the participants updated their concept lists based on information items that they had located on the web (e.g., Figure 2).

1. The cancer disease
2. The influences of cancer
3. Hospital
4. People with cancer
5. Radiation
6. Chemotherapy
7. Smoking
8. *Cancer of lungs*
9. *Metastasis*

Figure 2: An example concept list of a team (translated) based on the inquiry question: What is the influence of cancer on different people? (The team's inquiry theme was "Diseases"). The list was constructed by the team before the search and updated after the search (*the concepts in Italics*).

The control group searched for information on the web as well. At the end of the search, the students in all the three groups completed preparing their projects (8 lessons).

3 Results

Seven students (mostly students with learning disabilities) that did not complete the study requirements, dropped from the analyses. There were no statistically significant differences among the students in the various groups regarding their reading comprehension ($F(2, 75) = .69$, $p = .50$), and experience in using computers and web usage (frequencies analyses). The students were pre-assigned to teams and there was no statistically significant difference among the three groups regarding the teams' sizes ($M = 2.89$, SD = .64, Range: 2 - 4, $F(2, 24) = 2.05$, $p = .15$).

We analyzed the number of information items that were obtained at the end of the search process and their quality, by evaluating the relevance of each item for the inquiry question on a 3 point scale: 0 – no relevance, 1 – indirect relevance, 2 – direct relevance. This evaluation was performed independently by two school teachers (Kappa = .70). The average evaluation of the two judges was used in the analyses. The results by the three groups are presented in Table 1. The results of the study indicate that following search, students who constructed concept maps or lists, identified items of better quality compare with the control ($F(2, 26) = 7.37$, $p < .01$, $\acute{\eta}^2 = .38$). No significant difference was found between the map and the list groups. There was no statistically significant difference between groups regarding number of items retrieved ($F(2, 26) = .31$), and a marginal difference for the sum of information quality ($F(2, 26) = 3.09$, $p = .06$, $\acute{\eta}^2 = .20$).

Group	Number of teams	Number of items	Average of quality per item	Sum of items quality
Concept mapping	9	3.00 (1.32)	1.97 (0.55)	6.22 (3.76)
List	9	2.67 (0.87)	1.65 (0.53)	4.44 (2.14)
Control	9	2.67 (0.87)	0.97 (0.6)	2.83 (2.52)
Total	27	2.78 (1.01)	1.53 (0.69)	4.50 (3.12)

Table 1: Average number of retrieved items, average item quality (0-2) and quality sum for the three study groups (and standard deviations)

We compared the number of concepts as well as the number of the relevant concepts before and after the search for the concept map and the list groups (see Table 2). Analyzing the total number of concepts, there are overall more than twice as many concepts in the concept maps compared with the lists ($F(1, 16) = 25.21$, $p < .001$, $\acute{\eta}^2 = .61$) and they increased after the search ($F(1, 16) = 19.42$, $p < .001$, $\acute{\eta}^2 = .55$). However, there was no statistically significant interaction regarding the change in number of added concepts after the search ($F(1, 16) = .95$, $p = .34$, $\acute{\eta}^2 = .06$). A

similar pattern was obtained regarding the number of relevant concepts. There are overall more than twice as many relevant concepts in the concept maps compared with the lists ($F(1, 16) = 22.60$, $p < .001$, $\acute{\eta}^2 = .58$) and they increased after the search ($F(1, 16) = 24.70$, $p < .001$, $\acute{\eta}^2 = .60$). However, there was no statistically significant interaction regarding the change in number of added concepts after the search ($F(1, 16) = .19$, $p = .67$, $\acute{\eta}^2 = .01$).

		Number of concepts		Number of relevant concepts	
Group	**Number of teams**	**Before search**	**After search**	**Before search**	**After search**
Concept mapping	9	16.11 (4.31)	22.56 (8.90)	14.00 (3.78)	17.78 (6.82)
List	9	6.56 (1.74)	10.67 (2.65)	5.44 (1.79)	8.61 (2.70)
Total	18	11.33 (5.86)	16.61 (8.83)	9.72 (5.26)	13.19 (6.89)

Table 2: Average number of total and relevant number of concepts (and standard deviations), before and after search, for the concept mapping and the list groups

The quality of the inquiry projects was also independently evaluated by two school teachers that were not involved in the inquiry, based on eight criterions (Kappa range: .58 - .92, Median = .83), each consisting three levels (1-3), as presented in Table 3.

Criterion \ **Level**	**Level I**	**Level II**	**Level III**
1. Inquiry question	No inquiry question is included in the project	No reference in the project to the inquiry question	The project is focused on the inquiry question
2. How information items are used in the project	No use of retrieved information items in the project, or, the items are irrelevant to the inquiry question	Partial use of retrieved information items in the project	The information items are integrated in the projects
3. Inquiry conclusions	No stated conclusion from the inquiry process	The project's conclusion does not relate to the inquiry question	There is a stated conclusion and it relates to the inquiry question and generalizations based on the new acquired information
4. Relations among sections of the project	No coherent relations among the sections	There are very few coherent relations among the sections	Coherent relations among the project's sections
5. Clarity of written expression	Unclear, vague or cumbersome expression	Few clear and precise expressions	Clear and precise expressions
6. Project structure	The project is partially structured, with missing sections or with no clear separation between sections	The project is structured but one of the important sections is missing	The project is well structured
7. Inclusion of pictorial information	No pictorial information included	Including at least one picture, without any reference to it in the project	Including at least one picture, with reference to it in the project
8. Aesthetic presentation	No appropriate graphical elements. Mostly in draft format, not printed and with no cover page	Few appropriate graphical elements. Clean, printed, with a cover page	Appropriate graphical elements. Clean, printed, with a cover page

Table 3: The criterions of the inquiry project's evaluation on three levels

The projects evaluations results are presented in Table 4. A multivariate ANOVA of the quality of the inquiry projects indicated an overall difference among the three groups ($F(16, 34) = 6.55$, $p < .01$, Wilks Lambda = .060).

Separate ANOVAs for each criterion indicated statistically significant differences among groups for all the criterions, except criterion 7: (1) Inquiry question: ($F(2, 24) = 8.13$, $p < .01$, $\acute{\eta}^2 = .40$); (2) How information items are used in the project: ($F(2, 24) = 35.34$, $p < .01$, $\acute{\eta}^2 = .75$); (3) Inquiry conclusions: ($F(2, 24) = 10.1$, $p < .001$, $\acute{\eta}^2 = .46$); (4) Relations among sections of the project: ($F(2, 24) = 57.33$, $p < .01$, $\acute{\eta}^2 = .83$); (5) Clarity of written expression: ($F(2, 24) = 4.72$, $p < .012$, $\acute{\eta}^2 = .28$); (6) Project structure: ($F(2, 24) = 15.3$, $p < .01$, $\acute{\eta}^2 = .56$); (7) Inclusion of pictorial information: ($F(2, 24) = .80$, $p = .461$, $\acute{\eta}2 = .06$); (8) Aesthetic presentation: ($F(2, 24) = 3.92$, $p < .05$, $\acute{\eta}^2 = .25$).

Post hoc comparisons ($p < .05$) between groups indicated that the quality of the inquiry projects of the concept map group was higher than the list group (criterions 2, 4); that of the concept map group was higher than the control (criterions 1- 6, 8); and that of the list group was higher than the control (criterions 1- 4, 6, 8).

Criterion		**(1) Inquiry question**	**(2) How information items are used in the project**	**(3) Inquiry conclusions**	**(4) Relations among sections of the project**	**(5) Clarity of written expression**	**(6) Written project structure**	**(7) Inclusion of pictorial information**	**(8) Aesthetic presentation**
Group	**N**								
Concept mapping	9	2.72 (0.44)	3 (0)	2.67 (0.5)	2.89 (0.33)	2.28 (0.57)	2.39 (0.49)	2.28 (0.44)	2.72 (0.44)
List	9	2.56 (0.53)	2.33 (0.5)	2.11 (0.78)	1.61 (0.42)	1.78 (0.56)	2.06 (0.17)	2.44 (0.46)	2.61 (0.49)
Control	9	1.89 (0.42)	1.44 (0.46)	1.39 (0.49)	1.11 (0.33)	1.5 (0.5)	1.33 (0.5)	2.17 (0.5)	2.11 (0.55)
Total	27	2.39 (0.58)	2.26 (0.75)	2.06 (0.79)	1.87 (0.87)	1.85 (0.62)	1.93 (0.6)	2.3 (0.47)	2.48 (0.55)

Table 4: Means (and standard deviations) of project evaluations (1-3) by criterions and by groups.

4 Discussion and Summary

We found differences among the groups in the quality of information obtained following the search on the web. The quality of obtained information of the concept map and the list groups was better than the control, whilst between the map and the list groups there were no significant differences in information quality. However, we noticed that the initial number of concepts included in the concept maps was significantly larger than the number of concepts in the initial lists. Apparently, the maps are better tools for brain storming prior knowledge than lists. Analyzing additional documents following search, did not reveal a differential increase in the number of concepts (total or relevant) added to the maps or to the lists. However, the differences between the maps or the lists formats are expressed in the quality of the inquiry projects. In two evaluation criteria (How information items are used in the project; relations among sections of the project) of the inquiry projects, there was an advantage for the map group over the list. We propose that a larger number of relevant information items that were included in the maps, were integrated in the projects, reflecting better understanding of the retrieved documents. Also, the relations among sections of the projects reflect relationships between concepts in the maps.

We should note that the experimental manipulations focused on guiding the students in constructing maps or lists for the purpose of activating prior knowledge, and they did not focus intensively on exercising and applying a comprehensive search model. Subsequently, we found that maps or lists were updated following search through addition of concepts, but they were not reorganized. Generally, no concepts were deleted following search and no list or map reorganization was noted.

This study exhibited differential effects of applying graphic organization tools during different stages of information search and information use. The locus of the effect was located in this study at the stage of information use. However, we propose to further study possible effects at the search stage under different schedules of applying search models with various cognitive tools. Such a study should trace the entire search process, including the construction and modification of the search queries.

5 References

Bates, M. J. (1987). How to use information search tactics online. Online, May, 47-53.

Borgman, C. L. (1987). The study of user behavior on information retrieval system. Outlook – Information Retrieval, 19(3-4), 35-48.

Carnot, M. J., Dunn, B., & Canãs, A. J. (2000). Concept maps vs. web pages for information searching and browsing. Institute for Human and Machine Cognition. University of West Florida. Retrieved November 29, 2004 from http://www.ihmc.us/users/acanas/Publications/CONCEPT MAPapsVSWebPagesExp1

Collins, A., & Ferguson, W. (1993). Epistemic forms and epistemic games: Structures and strategies to guide inquiry. Educational Psychologist, 28(1), 25-42.

Jonassen, D. H. (1998). Concept mapping and other formalisms as mindtools representing knowledge. Pennsylvania State University. http://www.icbl.hw.ac.uk/projects/class/granum/altdocs/dav_alt.htm

Kozminsky, E. (1992). *A* graded difficulty test scale for evaluation of reading comprehension. Beer-Sheva, Israel: Ben-Gurion University of the Negev.

Kozminsky, E., & Nathan, N**.** (in preparation). The contribution of text concept mapping and language of thinking to inquiry learning.

Nathan, N. (2002). The effect of teaching language of thinking through concept mapping on inquiry learning. Doctoral dissertation. Ben-Gurion University.

Nathan, N., & Kozminsky, E. (2004). Text concept mapping: The contribution of mapping characteristics to learning from texts. Proceeding of the First International Conference on Concept Mapping, Pamplona, Spain, 2004**.**

Novak, J. D. (Retrieved April, 2004). The theory underlying concept maps and how to construct them. Available: http://cmap.coginst.uwf.edu/info/printer.html.

Payton, T. (1999). Searching strategies tips. Retrieved November 29, 2004 from http://www.tammypayton.net/courses/search/concept.shtml

Roth, W. M., & Roychoudhury, A.. (1993). The concept map as a tool for the collaborative construction of knowledge: A microanalysis of high school physics students. Journal of Research in Science Teaching, 30(5), 503-534.

Vilberg, T. (1996). Using concept mapping in a sensation & perception course. Paper presented at the National Institute for the Teaching of Psychology, St. Petersburg Beach, FL.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

EL CONTROL METACOGNITIVO DE LA BORROSIDAD DECRECIENTE EN LA ELABORACIÓN DE MAPAS CONCEPTUALES

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Resumen. La existencia del pensamiento borroso o difuso, así como del "sentido común" alternando con el pensamiento lógico clásico en el enfrentamiento de situaciones problemáticas y de aprendizaje, ha sido detectada por nuestro grupo de investigación en forma reiterada. En particular, en lo referente al aprendizaje de los conceptos científicos estandarizados, ha sido objeto de nuestra especial atención. En el contexto del desarrollo y manejo de las habilidades cognitivas básicas, que constituye una de las líneas de investigación que cultivamos, hemos abordado el problema de la borrosidad que aparece en los primeros intentos de construcción de mapas conceptuales sobre los conceptos físicos y los conceptos epistemológicos. Hemos avanzado una investigación sobre la acción de la metacognición del estudiante como agente en la disminución de la borrosidad inicial, con la finalidad de alcanzar una verdadera comprensión de esos conceptos expresada en términos de lenguaje lógico clásico, para alcanzar el status estándar de esa expresión. En este trabajo se da cuenta de los resultados actuales de esa pesquisa, realizada bajo la modalidad de investigación cualitativa sobre un grupo de veintiséis estudiantes de la Maestría en Enseñanza Aprendizaje de la Física en la Universidad Nacional Experimental del Táchira, UNET, San Cristóbal, Venezuela, abocados al tema de comprensión de los diferentes modelos epistémicos enseñados, utilizando mapas conceptuales como instrumento auxiliar del aprendizaje y como expresión de las individuales perspectivas de ese tema.

1 Introducción

En la búsqueda de soluciones a los innumerables problemas que presentan los alumnos para el aprendizaje de las Ciencias a nivel universitario se ha detectado que los alumnos de la Universidad Nacional Experimental del Táchira (UNET) y algunos profesores tienen dificultades para captar de manera global la información que reciben y para poder construir un esquema organizador del tema en estudio que les permita ubicar en algún tipo de estructura organizada los diversos conceptos. Les resulta también difícil poder establecer alguna relación entre diversos conceptos, especialmente en temas complejos y la mayoría tiene un manejo poco efectivo de técnicas de representación, información y resumen.

El aprendizaje significativo de las ciencias requiere que los alumnos incorporen a sus estructuras cognitivas conceptos significativos relacionados con las diversas ciencias (Ausubel,1976), y se sabe también que el aprendizaje puede ser facilitado si se emplean técnicas adecuadas de representación de información y de resumen(Pozo y Monereo, 1999). En este sentido los Mapas Conceptuales (Novak y Gowin, 1988) han demostrado ser una herramienta valiosa que puede ayudar a compensar muchos de los problemas mencionados anteriormente, como se demostró en innumerables trabajos presentados en el marco del Primer Congreso Internacional de Mapas Conceptuales realizado en Pamplona, en el 2004 (CMC, 2004).

Se reporta aquí una experiencia desarrollada con un grupo de profesores de enseñanza media y universitaria, alumnos de la Maestría en Enseñanza-Aprendizaje de las Ciencias Básicas de la Universidad Nacional Experimental del Táchira, UNET, Venezuela, quienes utilizaron los mapas conceptuales para la comprensión de estructuras conceptuales complejas en un tema, como es el de los modelos epistémicos en la asignatura Ciencia y Filosofía.

Para ello se elaboró y ensayó una estrategia metacognitiva enfocada a disponer pasos sucesivos de depuración de los mapas conceptuales que ellos construyeran, buscando en todo momento afianzar el ejercicio de la metacognición en cada uno de los participantes.

2 Mapa Conceptual y sus Usos

El mapa conceptual es una herramienta heurística que facilita al estudiante la construcción del conocimiento. Un Mapa Conceptual consiste de una *representación gráfica* que muestra una serie de *conceptos* unidos a través de *palabras enlace* para formar *proposiciones*, es decir oraciones que tienen un valor de verdad. Así se van formando estructuras conceptuales de las uniones de diversas proposiciones. Se parte de un *concepto inclusor* y a partir de él se van construyendo las relaciones con otros *conceptos subordinados.* En la construcción de un mapa se evidencian

los principios básicos del aprendizaje significativo: principio de organización jerárquica, diferenciación progresiva y reconciliación integradora.

El Mapa Conceptual tiene muchos usos. Fue concebido originalmente por Novak como herramienta heurística a ser utilizada por el alumno para captar el significado de una estructura conceptual y ha resultado ser una herramienta muy poderosa que puede ser utilizada por los profesores para presentar información, para evaluar y para orientar el diseño instruccional de sus experiencias de aprendizaje. También la pueden emplear los alumnos para construir su propio conocimiento de manera grupal, para organizar la comprensión de un tema y para presentar sus trabajos.

Actualmente en nuestra universidad, la UNET, se utilizan los mapas en algunas asignaturas para apoyar el desarrollo de cursos presenciales. En Física I los usamos con los alumnos mediante una estrategia descrita en un trabajo anterior y presentada en el marco del Primer Congreso de Mapas Conceptuales (Ramírez de M. y Sanabria, 2004). Concretamente ayudan a los alumnos en la construcción de conceptos de Física, la comprensión de estructuras conceptuales y para orientar la resolución de problemas. Hemos utilizado también los mapas para diversos fines. Se emplean para orientar el proceso de diseño instruccional de los materiales que colocan algunos profesores en la red y actualmente los hemos convertido también en herramienta indispensable en la formación de profesores que realizan cursos de Maestría en Enseñanza-Aprendizaje de las Ciencias Básicas. Nuestro interés en este caso era investigar la utilidad de los mapas como herramienta para los mismos profesores, estudiantes de maestría, para la comprensión de estructuras conceptuales complejas en temas con los que se enfrentan por primera vez, como es el caso de Filosofía y los modelos epistémicos y ensayar una estrategia que fuera efectiva para tal fin.

3 El problema

En la realización de mapas conceptuales por los alumnos, con la intención de expresar un concepto o una cadena de conceptos estudiados por ellos, solemos encontrar características difusas o borrosas. Esta situación da origen a las siguientes consideraciones.

Primero, una mapa conceptual debe expresar un concepto o una cadena de conceptos en términos de un lenguaje lógico que se pretende sea objetivo, universal y preciso; objetivo en el sentido de que se refiera específicamente al concepto o cadena de conceptos al que apunta; universal en el sentido de que todas las personas que conozcan el contexto del tema puedan interpretarlo de la misma manera; preciso en el sentido de que constituya una representación distinta del concepto o cadena de conceptos apuntados.

Segundo, en la estructura cognitiva del alumno se encuentran diversos instrumentos o mecanismos de procesamiento de información como son la lógica clásica, la lógica difusa y el sentido común, además de un variado número de preconcepciones o concepciones alternativas de los conceptos científicos o filosóficos. Todos ellos están presentes en la mente del alumno a la hora de enfrentar cualquier situación problemática.

Tercero, es naturalmente válida la siguiente interrogante: ¿Será posible plantear una estrategia orientada a la depuración de los mapas conceptuales iniciales construidos por el alumno, que resulte práctica y efectiva para el aprendizaje significativo de estructuras conceptuales complejas?

4 La Solución Propuesta

Frente a esta problemática se decidió afrontar la tercera consideración expuesta con la elaboración y puesta en ensayo de una estrategia metacognitiva enfocada a disponer pasos sucesivos de depuración de los mapas conceptuales, inicialmente propuestos por un grupo de alumnos en un determinado tema.

5 La Experiencia

5.1 Muestra

Se seleccionó una muestra intencional (opinática) de alumnos constituida por un grupo de veintiséis estudiantes de primer semestre de la Maestría en Enseñanza Aprendizaje de las Ciencias Básicas de la UNET, dadas las ventajas prácticas de su acceso y observación por parte nuestra.

5.2 Estrategia utilizada

5.2.1 Taller de inducción a los mapas conceptuales

Se desarrolló un taller sobre mapas conceptuales de 16 horas de duración. Los participantes se familiarizaron con los mapas, construyeron definiciones de un mapa conceptual y sus elementos, desarrollaron mapas de tópicos que dominaban y construyeron algunos para la comprensión de temas sencillos que ellos desconocían. Este taller sigue algunas de las estrategias descritas en el trabajo presentado en el congreso anterior (Ramírez de M, M y Sanabria, I, 2004) y se apoya con el texto "El mapa conceptual como herramienta heurística para facilitar el aprendizaje" diseñado por uno de los autores de este trabajo (Ramírez de M., 2005).

5.2.2 Asignación de la tarea

En la asignatura Ciencia y Filosofía se eligió como tema "los Modelos Epistémicos", para lo cual se usó como fuente informativa el texto "El intelectual y los modelos epistémicos" de Barrera Morales (1999). Se señaló como tarea inicial (sin advertir a los alumnos su condición de inicial) la realización de un mapa conceptual que representara el aprendizaje individual de cada estudiante en el tema señalado.

5.2.3 Revisión de habilidades cognitivas básicas y metacognición

Se revisó con los participantes el tema ya estudiado en la Maestría relativo a las habilidades cognitivas básicas y la metacognición para que aplicaran lo aprendido en la construcción de sus mapas conceptuales

5.2.4 Análisis de los primeros mapas y depuración sucesiva de los mismos

Después de analizados los resultados y señaladas las características de borrosidad de que adolecían, se procedió a comunicarlas a cada alumno.

A cada uno de ellos se le solicitó la depuración del mapa conceptual original para su mayor aproximación a la objetividad, universalidad y precisión deseadas, indicándoles como guía u orientación en su trabajo el ejercicio consciente de su metacognición. Esto significó estimularlos a que revisaran sus mapas, evaluaran ellos mismos hasta que punto comprendían cada uno de los conceptos que habían incorporado al mismo, decidieran si era necesario organizar la búsqueda de más información, además de la que había en el texto, y tomaran decisiones de si continuaban tejiendo toda la información en un mismo mapa o iniciaban mapas separados para los diversos modelos epistémicos. Igualmente debían decidir si continuaban con los procesos de diferenciación progresiva de los diversos modelos epistémicos y de reconciliación integradora entre ellos.

Los nuevos resultados, después de analizados y comentados con cada alumno que así lo solicitó, dieron paso a otra depuración realizada por ellos.

Se fijó arbitrariamente un total de tres depuraciones para todo el proceso.

5.2.5 Construcción y utilización de un protocolo de análisis

Se les estimuló a que construyeran su propio protocolo de análisis para ir evaluando sus mapas con preguntas como: ¿Tengo claro el concepto de modelo epistémico? ¿Necesito saber eso para clasificarlos como dice el autor del texto? ¿Existen conceptos que yo creía eran iguales? ¿Cuáles? ¿Y son realmente diferentes? ¿En qué se diferencian? ¿Se entiende en el texto la esencia de cada modelo originario? ¿Y los que se derivan de él qué tienen en común con él y en qué se diferencian? ¿Muestra el mapa la esencia de esas diferencias? Además debían registrar, de ser posible sus respuestas y comentarios.

5.2.6 Entrega y revisión de los mapas conceptuales "finales".

Se recibieron los mapas pero se les pidió guardasen una copia de los mismos para seguirlos perfeccionando.

5.3 Técnicas e instrumentos

Las técnicas e instrumentos utilizados para evaluar la experiencia fueron los mapas conceptuales diseñados por los alumnos de la maestría; el registro escrito de observaciones y la grabación en audio hechas por algunos de ellos mientras construían los mapas y comentarios expresados por los mismos profesores.

La evaluación de los mapas por parte de los investigadores para inferir si había una borrosidad decreciente se hizo con el siguiente protocolo de análisis:

PROPÓSITO	*El aspecto más relevante del análisis es la detección de expresiones borrosas que se caracterizan por uno o más de los rasgos señalados a continuación.*
CATEGORÍAS DE ANÁLISIS	1. Ambigüedad por falta de precisión en la expresión de un concepto o un link 2. Error de lógica clásica. 3. Uso de lógica difusa. 4. Uso de preconcepciones. 5. Uso de concepciones erróneas.

Tabla 1. Protocolo de análisis

Se pesquisaron esos rasgos para ubicarlos y comunicarlos a los alumnos. Se tomaron registros sucesivos de los mapas para tener evidencias de su eventual progreso.

6 Resultados obtenidos

6.1 Ejemplos y comentarios de algunos mapas conceptuales originales

- Ante la complejidad del tema, desconocido para ellos, algunos participantes se conformaron con establecer los modelos en una agrupación general sin determinar relaciones entre ellos (Figura 1).

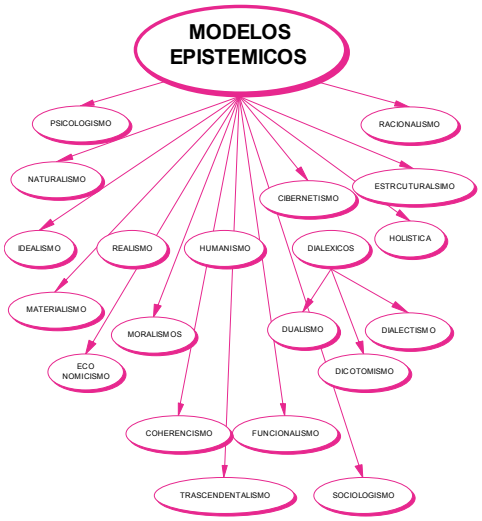


Figura 1. Ejemplo de Diagrama inicial

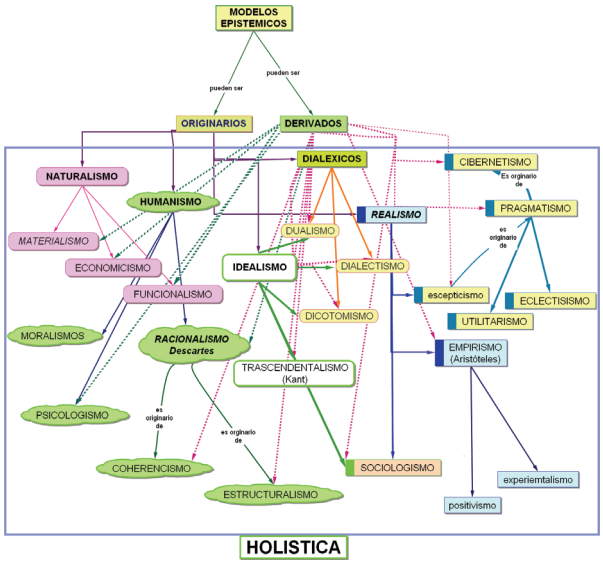


Figura 2. Ejemplo de Diagrama inicial con algunas relaciones

Un participante se limitó a buscar información sobre los filósofos que tenían que ver con cada modelo epistémico y año en que surgieron sin construir conceptos. Otros hicieron un diagrama general y lograron separar los modelos en originarios y derivados (Figura 2) y después aclararon las características de cada modelo en tablas, sin

lograr realmente construir mapas de ellos. Al explorar más esos trabajos, se evidenció una fuerte orientación conductista en esos participantes, que les dificulta incorporar los mapas conceptuales a su estructura cognitiva como herramienta heurística para facilitar el aprendizaje del tema en cuestión. Surgen comentarios como *"Si a uno no le explican primero, es imposible aprender de modelos epistémicos sólo con lo que dice en el texto"*, sin pensar que ellos están en capacidad de buscar más información, organizarla y analizarla. O *"Es mas fácil hacerlo en tablas separadas"* sin notar que las tablas no obligan al aprendiz a establecer semejanzas o diferencias y relaciones entre los conceptos.

Igualmente resultó difícil para algunos participantes conseguir palabras enlaces que realmente expresaran algo mas allá de la simple relación de dependencia "*es originario de*" o bien "*se deriva de*" (Nota: en el texto con el que trabajaron se plantea que existen cinco modelos epistémicos originarios y quince derivados).

6.2 Ejemplos y comentarios de algunos mapas conceptuales sucesivos

- Al irse complicando los mapas, los participantes comienzan a recurrir a códigos de organización que faciliten la tarea. Surgen reflexiones como las siguientes: "Debo distinguir las ramas del mapa central. *¿Lo puedo hacer con colores? ¿O cambio las formas de los recuadros para cada modelo?; ¿Se ve alguna relación cruzada entre los diversos modelos epistémicos?*
- Los participantes comienzan a hacer metacognición sobre el trabajo que han realizado cuando ven que no logran visualizar semejanzas y diferencias entre los modelos epistémicos originarios y los derivados, ni las relaciones entre ellos.
  Un participante señala:
  "Me pregunté: ¿Qué debo hacer para entender las relaciones entre ellos? Pienso que se debe comenzar a entender los atributos fundamentales que distinguen cada una de las categorías originarias (modelos epistémicos originarios) para ver si es posible comprender cómo se relacionan los derivados con ellos. Conseguir que tienen en común. Voy a hacer mapas por separado de cada modelo epistémico originario y después veré como se relacionan".
- Los participantes se dan cuenta de la necesidad de replantear las estrategias que han utilizado para la construcción del mapa y lo que saben de los diversos conceptos, empleando su metacognición. Se hacen preguntas como *¿He comprendido correctamente este concepto? El mapa refleja lo que el autor dice de este modelo, pero...¿entiendo de verdad lo que significa? ¿Me dice algo? ¿Comprendo de verdad lo que significa cada modelo? ¿Soy capaz de repetir en mis propias palabras lo que significa cada modelo epistémico? ¿Debo buscar mas información?*
- La mayoría logra comprensión de cada modelo epistémico por separado (ver ejemplo en Figura 3), pero se les dificulta la integración de diversos modelos y establecer una reconciliación integradora entre ellos.

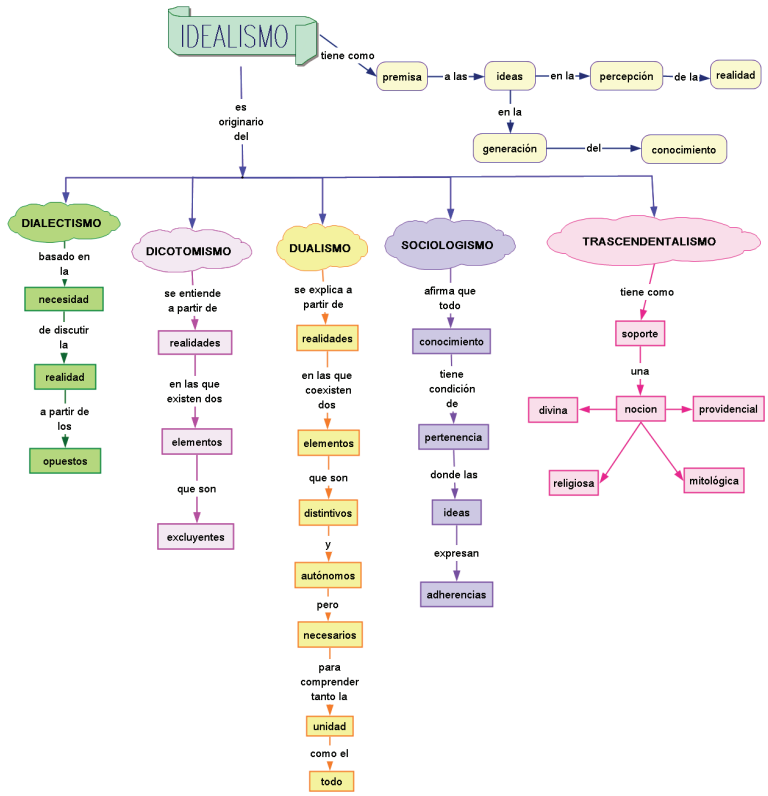


Figura 3. Ejemplo de Mapa Conceptual del Modelo Epistémico Idealismo

- Algunos mapas son más elaborados que otros e incluyen información no suministrada en el texto lo que demuestra que han buscado adecuadamente información en otras fuentes (Figura 4).

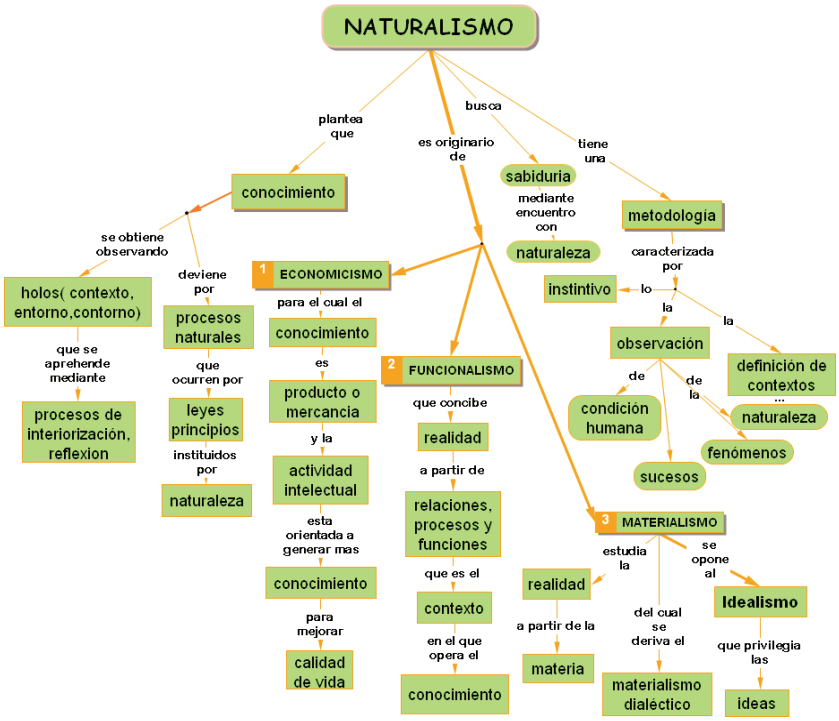


Figura 4. Ejemplo de Mapa Conceptual del Modelo Epistémico Naturalismo

6.3 *Ejemplos y comentarios de algunos mapas conceptuales finales*

- Algunos participantes lograron la construcción de un mapa global donde se incluyen todos los modelos epistémicos (Figura 5). Según uno de ellos: *"La visión global facilita la ubicación de cada modelo en la correspondiente categoría y los detalles los busca uno después"*. Otros optaron por elaborar mapas para cada modelo e incluir solo las relaciones más importantes con otros modelos epistémicos.

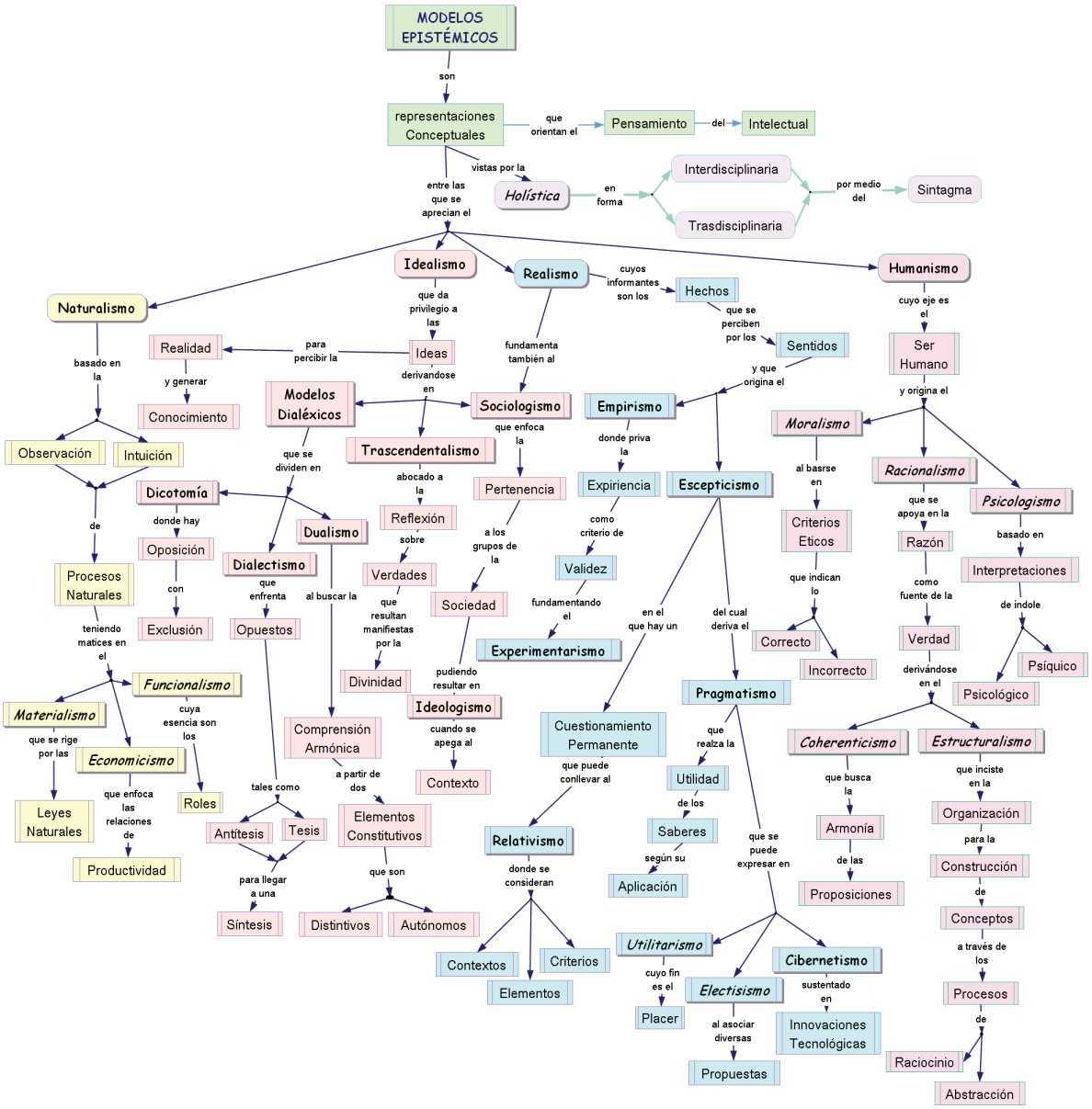


Figura. 5 Ejemplo de Mapa Conceptual de los Modelos Epistémicos de un participante

Algunos participantes se muestran orgullosos de la comprensión que lograron del tema. Esta se refleja en la capacidad de síntesis e integración de conceptos en categorías y en los enlaces empleados para relacionar algunos de los modelos epistémicos. La borrosidad decreciente se aprecia por ejemplo en la sucesiva construcción de relaciones entre modelos epistémicos. Por ejemplo entre los modelos del realismo y el humanismo, se observó la evolución de algunas proposiciones a lo largo de los mapas sucesivos. De expresiones borrosas o difusas como: *"Realismo se relaciona con Humanismo"*o bien "*Realismo tiene que ver con Humanismo*" comienzan a aparecer proposiciones como: *"Humanismo es originario de racionalismo que tiene que ver con lo del método deductivo"* o bien:

"Humanismo es originario del racionalismo y el realismo es originario del empirismo". En el último mapa de este participante (Figura 6), se observa como logra relacionar dialéxicamente el racionalismo y el empirismo y establecer que se sintetizan en el método hipotético deductivo.

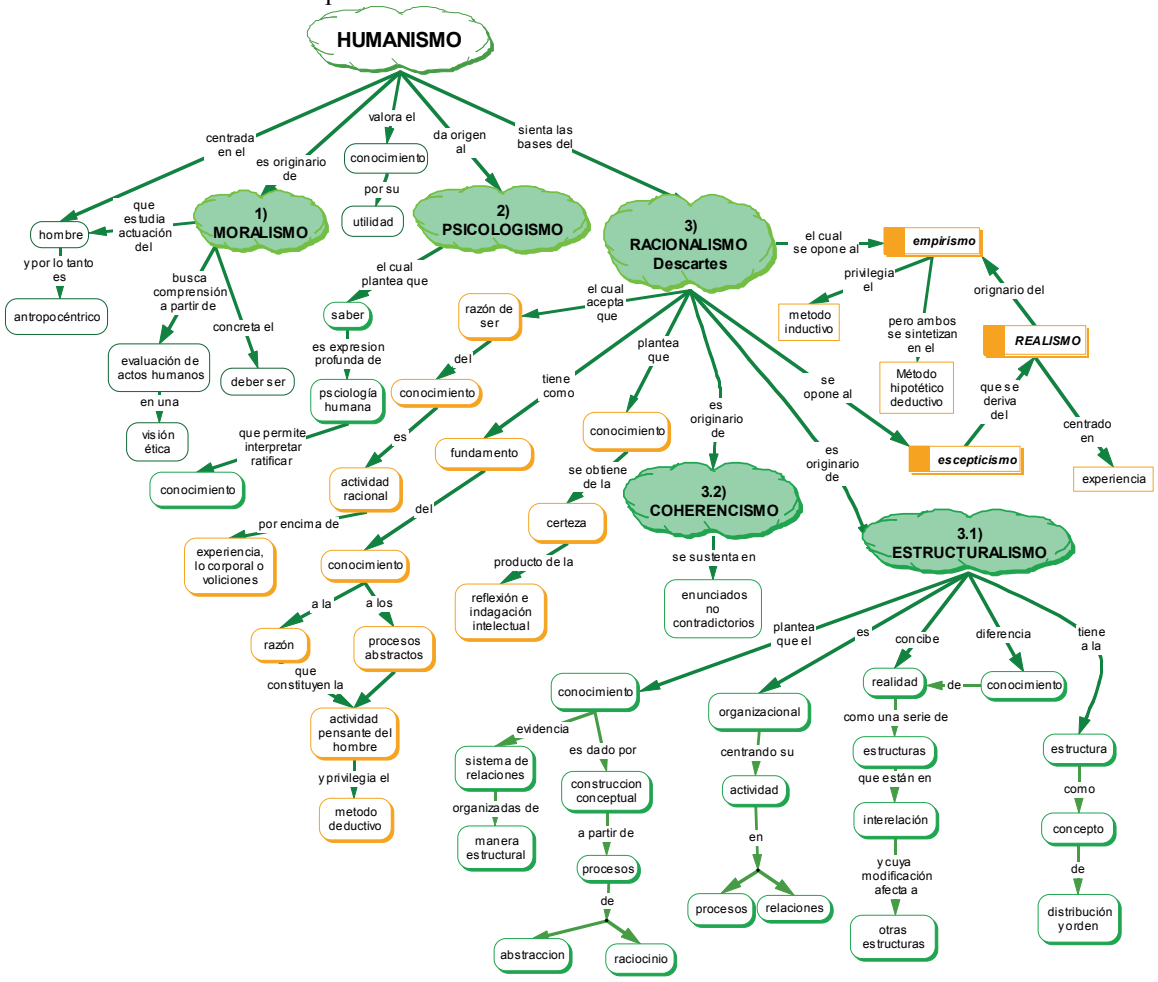


Figura 6 Ejemplo de Mapa conceptual del Humanismo mostrando relaciones con el Realismo

Los participantes coinciden en manifestar que:

- La comprensión de textos complejos es facilitada por la construcción de mapas.
- El mapa permite la consulta inmediata de toda la estructura conceptual al toparse en algún texto con alguno de los modelos epistémicos para ubicarlo en su real contexto.
- La metacognición consciente facilita la construcción de los mapas y el aprendizaje significativo. La reflexión sobre cada paso dado y la búsqueda de sentido a lo que se ha plasmado en el mapa, le permite al participante darse cuenta cuando un concepto ha sido realmente comprendido.
- El texto suministrado les resulta insuficiente para comprender este tema tan complejo, pero la organización y construcción de los mapas y el intento de lograr una borrosidad decreciente los obliga a buscar ordenadamente más información en otras fuentes para aclarar, reforzar o refutar las opiniones emitidas por el autor del texto.
- Los participantes están en capacidad de expresar en sus propias palabras el concepto de la mayoría de los modelos epistémicos, mas no así de las relaciones entre muchos de ellos.
- Algunos participantes descubren que entre los modelos originarios hay relaciones dialéxicas y por lo tanto, en una primera aproximación a un tema desconocido para ellos, no tiene sentido forzar unas relaciones mas allá de saber que dos modelos se oponen, se excluyen o se complementan. Esta convicción les permitió establecer un mapa conceptual simple que los relacionara y mapas separados que explicaran cada modelo.
- Se requiere mas tiempo para realizar una tarea compleja como esta.

7 Conclusiones

- La psicodiversidad presente en el grupo se manifestó en los diferentes enfoques con que se abordó la tarea inicial de construcción de los mapas así como en los diferentes términos usados para expresar las características de cada concepto y en los enlaces entre ellos.
- Estos rasgos continuaron presentándose en los sucesivos mapas conceptuales producto de las sucesivas depuraciones.
- La mayoría de los alumnos evidenciaron mejoría en su aproximación a una claridad y extensión de las sucesivas representaciones de mapas conceptuales, como se puede observar en los ejemplos de mapas ¨finales¨ que se presentan en este trabajo.
- La estrategia adoptada parece ser un buen camino para afianzar el ejercicio de la metacognición en cada alumno, a la vez que para el perfeccionamiento de los mapas conceptuales en donde los participantes dan cuenta del aprendizaje logrado en cualquier tema.
- Las evaluaciones cualitativas realizadas a partir del análisis de los mapas conceptuales diseñados por los profesores participantes y de sus opiniones, permiten afirmar que la estrategia ha sido adecuada y se presenta como un elemento promisorio que contribuye al logro de un aprendizaje significativo de una estructura conceptual compleja.
- Los Mapas Conceptuales ayudan al estudiante a desarrollar su capacidad de síntesis y le permiten ejercitar su metacognición. La reflexión sobre cada paso dado y la búsqueda de sentido a lo que se ha plasmado en el mapa, le permite al participante darse cuenta cuando un concepto ha sido realmente comprendido.
- La resistencia que aún ofrecen algunos profesores a incorporar los mapas conceptuales a su metodología de aprendizaje, obedece a una orientación conductista tan marcada que les dificulta el contemplar nuevas posibilidades de acción, donde ellos mismos puedan construir más activamente su propio conocimiento al reflexionar sobre los conceptos e intentar conseguir una borrosidad decreciente de los mismos empleando su metacognición.
- La estrategia de construcción de mapas a través de sucesivas depuraciones, utilizando la metacognición, parece ser prometedora para el logro de un aprendizaje significativo por lo que se recomienda continuar utilizándola y extender su uso para la comprensión de otras estructuras conceptuales complejas.

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9 Referencias

Ausubel, D. (1976). *Psicología Educativa*. México: Trillas.

Barrera Morales, M. (1999). *El intelectual y los modelos epistémicos*. Caracas: Sypal

CMC (2004). *Actas del Primer Congreso de Mapas Conceptuales CMC 2004*. Universidad Pública de Navarra. Disponible en: **http://cmc.ihmc.us/CMC2004Programa.html**. [Consulta: 2006, Abril 1].

Novak, J. D. y Gowin, D. B. (1988). *Aprendiendo a Aprender*. Barcelona: Martínez Roca.

Novak, J. D. (2003). *The Theory Underlying Concept Maps and How To Construct Them*. Disponible en: **http://cmap.coginst.uwf.edu/info/**. [Consulta: 2004, Abril 15].

Pozo, J. y Monereo, C. (Comps.). (1999). Un Currículo para aprender. Profesores, Alumnos y Contenidos ante el aprendizaje Estratégico. *El Aprendizaje Estratégico*, (70), 11-25. Madrid: Aula XXI/ Santillana.

Ramírez de M., M. (2005). *El Mapa Conceptual como Herramienta Heurística para Facilitar el Aprendizaje*. San Cristóbal: Fondo Editorial de la UNET.

Ramírez de M. M, y Sanabria, I. (2004). *El Mapa Conceptual como elemento fundamental para el aprendizaje de la Física a nivel universitario*. Actas del Primer Congreso de Mapas Conceptuales CMC 2004. Universidad Pública de Navarra. Disponible en: **http://cmc.ihmc.us/papers/cmc2004-086.pdf** [Consulta: 2005, Noviembre 1].

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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EL MAPA CONCEPTUAL Y LA NARRATIVA HISTÓRICA

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Abstract. En este trabajo se reflexiona acerca del mapa conceptual como un instrumento que sirve al historiador en el proceso de construcción de la narrativa histórica, se concibe también como un medio para representar y contener la narrativa y por tanto para representar el conocimiento histórico. Se distinguen dos aspectos de la construcción del conocimiento histórico. Por una parte la actividad de la investigación y por otro la escritura de la narrativa histórica. Aunque ambos son parte de un mismo proceso son momentos distintos de la construcción del conocimiento. En la actividad de la investigación el mapa conceptual es un instrumento para el desarrollo de conceptos por lo que puede considerarse una herramienta semiótica y heurística. La *escritura* de la narrativa, que depende de la actividad investigativa, supone un proceso de comunicación a un lector, el mapa conceptual puede servir como un instrumento de escritura y una forma de organizar la narrativa. Este texto se dirige a dos comunidades disciplinarias, por una parte a los historiadores para describir a ellos, en términos propios de la disciplina, las funciones en la hermenéutica y heurística del mapa conceptual, por otra parte se comparte, con la comunidad educativa y de investigación sobre mapas conceptuales, una visión que pretende diversificar y redescribir una herramienta cuya versatilidad desborda el campo educativo y psicológico. Se discuten también algunos aspectos sobre la *representación* del conocimiento *en construcción* y las tensiones que supone esto con un sistema de representación que implica la representación del *conocimiento concluido*, al menos en su forma *proposicional*.

1 El aprendizaje y la investigación, dos formas distintas de construir conocimiento

El mapa conceptual ha sido fundamentalmente una herramienta didáctica en las ciencias sociales, en particular en la enseñanza de la historia (López Serra, 2002). Su empleo en estas circunstancias, aunque orientado a lo didáctico, resulta valioso para dejar expuestas ciertas operaciones "ocultas" en la producción de conocimientos cuando estos son presentados en textos escritos o iconográficos. En ese sentido, el mapa conceptual "descubre" la red de conceptos que han servido para interpretar y construir una narrativa.

Las funciones del mapa conceptual en el contexto del aprendizaje escolar son diferentes al contexto de la investigación, aunque el investigador utilice el mapa conceptual con fines de aprendizaje esta actividad tiene propósitos y motivaciones distintas al de un aprendiz. El punto en común del aprendizaje escolar y el aprendizaje en la investigación, apoyado con el mapa conceptual, es el proceso metacognitivo que propicia, es decir, reflexiones acerca de los propias formas de aprender y del uso de determinadas habilidades y estrategias para favorecer el aprendizaje (Novak, 1998), sin olvidar que el aprendizaje y comprensión de una teoría son cualitativamente distintas en estudiantes, maestros e investigadores. El proceso metacognitivo en el investigador, por su función y dominio de conocimiento, se concentra en la creación de problemas y de hipótesis de trabajo, que deben estar en relación con perspectivas metodológicas, filosóficas y teóricas.

La *representación del conocimiento* es un proceso científico regulado por los paradigmas disciplinarios, métodos y técnicas disponibles (Locke, 1997). El mapa conceptual es una forma representación del conocimiento, como tal es una mediación entre la realidad y el concepto, entre los procesos de explicación y comprensión del mundo cultural y natural, entre la producción y representación del conocimiento, un modo específico de comunicación de resultados. Considerado lo anterior, el *mapa conceptual* es un recurso metodológico en la investigación que permite develar los procedimientos, comprender las relaciones entre el concepto y el conjunto de observaciones que el material empírico proporciona. Las *representaciones* de las relaciones conceptuales, en un proceso de constitución del problema y de la hipótesis, suponen un trabajo en la frontera entre conceptos estables y la construcción de nuevos conceptos y el establecimiento de nuevas relaciones, lo que descriptivamente es similar al proceso de aprendizaje, que además lo es, con la singularidad de que el investigador no tiene el reto de *adquirir un conocimiento disponible* sino de *hacer el conocimiento* y *presentarlo* para que esté disponible social y culturalmente.

En el campo de la historia y por las problemáticas propias de la actividad investigativa, el mapa conceptual deja de ser sólo un artefacto cognitivo para ser, en el contexto del *habitus* (Bourdieu, 2003) de la investigación disciplinaria, un *utillaje mental* (Chartier, 2002), cuya función es ayudar a construir nuevos objetos de investigación y construir nuevas formas de contar la historia.

2 *Habitus* y mapas conceptuales.

El mapa conceptual ha propiciado transformaciones en las formas del "pensar" y del "hacer" científico. Su expansión y diversificación puede dar lugar a cambios en las formas de escribir y leer. Su uso en la investigación ha sido una de sus primeras aplicaciones, Novak y su equipo utilizaron el mapa conceptual como herramienta para la comprensión de la teoría de Ausubel (Novak, 1998, p.75).

La adquisición y el aprendizaje de habilidades y destrezas mentales implican modificar las formas de concebir y elaborar el conocimiento independientemente de la disciplina científica y humanística de que se trate. Involucra un proceso de reflexión acerca de los modos de comprender, explicar, ordenar y representar la realidad ya sea natural o social. Por ello es necesario la constitución de nuevos *habitus*; la transformación de las disposiciones físicas y mentales para orientar los actos, las prácticas y los discursos en el mundo social (Bourdieu, 2003), para aprender y reproducir cambios y variaciones en los modos de ordenar y representar el mundo, en particular el mundo de la cultura, de la cual forman parte las ciencias en general. En ese sentido, la práctica de escritura del *mapa conceptual* es parte de la transformación del *habitus* y por ello es un objeto en tensión entre la resistencia y la innovación del instrumental (utillaje mental) del historiador.

El mapa conceptual condiciona los contenidos en la medida en que establece los límites de los actos de su escritura y lectura, se establece una tensión entre la pretensión del creador y la restricción del *habitus*. El creador elabora y sistematiza por medio de la formulación de problemas e hipótesis de investigación, conceptos y teorías para explicar la realidad mediante el conocimiento, ello implica un lenguaje, un discurso y una estructura narrativa, en otras palabras: el "autor" escribe la realidad, esto es, la descompone, la fragmenta, la examina, y la articula, para que un "lector" se apropie e interprete lo escrito. Como cualquier otro texto, el *mapa conceptual* se encuentra sujeto a las prácticas de lectura y escritura (Aguilar Tamayo, 2004, 2005) y en el caso del campo del conocimiento histórico también estará sujeto a las regulaciones y tensiones de las prácticas de investigación en la disciplina.

El *mapa conceptual* adquiere relevancia en los dos espacios, en la *escritura* y en la *lectura*. El *mapa conceptual,* como el texto escrito*,* es limitado y público (Aguilar Tamayo, 2004, , 2005), aunque todo autor busca controlar la lectura del lector esta se emancipa con base en sus experiencias, sus ideas, sus creencias, sus prácticas y la comunidad académica a la que pertenece, en suma, conforme a su *horizonte cultural* realiza el acto de "leer", dotando de sentido al conocimiento, a la realidad que éste representa (Gadamer, 1994). El mapa conceptual es un *medio* que condiciona lo que se dice, el modo en que se produce, se preserva, se transmite, se apropia y se dice, esto es, las maneras de interpretar la realidad, de percibirla, ordenarla y expresarla (Viñao Frago, 1999), como *técnica* el mapa conceptual es reproducible y transferible, es un *medio*. El *horizonte cultural* y el *habitus* de creadores y lectores son procesos de *potencia y restricción* a la práctica de escritura con mapas conceptuales.

3 Escritura y mapa conceptual

El mapa conceptual es un *texto* sujeto a la interpretación del lector. La producción y la interpretación dependen de contextos y prácticas. La técnica del mapa conceptual establece ciertas normas que hacen que la producción y la interpretación tengan un cierto grado de estabilidad. Sin embargo, de igual forma que ocurre con los textos escritos, la interpretación no sólo requiere de la comprensión de un código alfabético y visual, existen ideas, teorías y conceptos que sirven para dar *sentido* al texto que se construye o se lee. El *sentido* del mapa conceptual no es la suma de las proposiciones que lo componen, sino los significados que son representados por la proposiciones y que guardan relación con conceptos, teorías y contextos en los que se produce y lee (Aguilar Tamayo, 2004).

Las *representaciones externas* ayudan al pensamiento, ciertas operaciones lógicas o de razonamiento sólo son posibles si se apoyan en un sistema de representación externa (Aguilar Tamayo, 2005). Las notas y cuadernos de trabajo son un ejemplo de ello, también lo es el uso del sistema numérico y del álgebra para ayudar a resolver operaciones matemáticas (Wertsch, 1985). La *representación del conocimiento científico* toma formas específicas (Locke, 1997), por ejemplo, reportes de investigación, artículos y libros, sus convenciones de escritura y presentación ayudan a dar estabilidad a la construcción e interpretación de los

textos, sin embargo estos formalismos se aplican a un *texto final*, es decir, suponen que el documento que se presenta es un documento fijado y terminado, aún y cuando la investigación siga su curso.

La técnica del mapa conceptual orienta la realización de éste como un texto final. Debido a que la técnica requiere la representación de *proposiciones* para que se constituyan en una estructura proposicional, las proposiciones deben ser pretendidamente verdaderas, sin embargo, como es sabido en el ámbito de la investigación, la formulación de una simple proposición requiere de un proceso que permita su argumentación y su defensa. En el trayecto de la investigación se busca construir la proposición que de respuesta a la *pregunta o hipótesis de trabajo*. Si consideramos el mapa conceptual como una herramienta cuya utilidad no está sólo al final del proceso de investigación, es decir que no sólo es útil en el proceso de *re-representación proposicional* del conocimiento ya establecido, sino que se concibe como una *herramienta* que acompaña el *proceso de formulación proposicional,* que no es otro que el proceso de construcción del conocimiento, es factible imaginar que las formas del mapa conceptual pueden incluir relaciones entre concepto de manera *no proposicional*.

La representación *no proposicional* de las relaciones entre conceptos es una violación a la técnica del mapa conceptual, pero no a la teoría que lo sustenta ni a los propósitos de su uso. De la misma manera que este artículo ha surgido de párrafos inconexos o inacabados hasta alcanzar una estructura formal que incluye, tipografía, márgenes, segmentación de texto y titulado, presentación de imagen, formato de referencias y otras más, el mapa conceptual surge de conceptos, relaciones y jerarquías que *van tomando forma*, es decir, ajustando a las normas y convenciones de la técnica. En el plano del aprendizaje este proceso es valioso porque permite al estudiante cobrar conciencia de aquellas relaciones que no son claras y que requieren de mayor precisión, sin embargo, en el campo de la investigación, en el desarrollo mismo de la actividad investigativa, son las *relaciones inacabadas* el motivo del trabajo, que ciertamente en algún momento podrá definirse la relación, pero solo para hacer surgir nuevas relaciones y nuevos conceptos que permitirán establecer nuevas preguntas.

El mapa conceptual puede resultar útil para el trazo de ciertas relaciones, que si bien todavía no pueden ser definidas proposicionalmente, pueden sugerir "hipótesis proposicionales", o estrategias cuyo objetivo es derivar la proposición que falta para definir la relación. Otra forma de establecer relaciones entre conceptos es a partir de las hipótesis de trabajo. Una hipótesis expresada como una forma tentativa de relacionar conceptos podría originar un enunciado como el siguiente:

> "**La condición *X*** [que es un concepto] ***¿puede ser reconstruida a partir de?*** ***Y*** [un concepto, por ejemplo un evento]" (Ver el ejemplo de la figura 1 y su explicación).

Resulta evidente de que si se plantea la discusión en términos de la *técnica*, el enunciado anterior resulta inaceptable bajo las normas de elaboración del mapa conceptual, sin embargo, si el problema se plantea como un proceso de construcción de conocimiento y cómo este es auxiliado por metodologías y *utillajes mentales* la formulación de este tipo de enunciados, no pareciera contradecir el proceso de reflexión y construcción que supone la elaboración del mapa conceptual. En la figura 1.A, se muestra de manera generalizada, la forma proposicional de la relaciones entre conceptos tal y como se define por la técnica del mapa conceptual. En la figura 1.B, se muestra un ejemplo hipotético de cómo podría utilizarse el mapa conceptual en el proceso de constitución de las proposiciones. En este ejemplo el establecimiento de las relaciones X, Y, Z tiene un significado importante para definir la perspectiva de la investigación, en el caso de W sirve para preguntarse si se requiere el estudio y la comprensión de otro fenómeno (W) considerado como parte de la *problemática* que se representa con X. La figura 1 es un modelo simplificado, evidentemente estas estructuras pueden constar de más conceptos y de variaciones en las relaciones, algunas proposicionales y algunas otras servirán para plantear la hipótesis de trabajo.

La representación del *conocimiento en proceso y transformación* escapa a la mayoría de los sistemas de representación. El texto impreso y el mapa conceptual, pueden capturar una parte del proceso, y expresarla *como si* el conocimiento alcanzado fuera un producto terminado, sin que esto signifique desconocer que el proceso de construcción del conocimiento y del aprendizaje es continuo y sin final. Lo que se representa, sin embargo, es un momento del *estado* de lo conocido y/o lo aprendido, los resultados de la actividad y no propiamente el *proceso*, aunque esto último puede investigarse a partir la comparación en el tiempo de mapas conceptuales y puedan ser interpretados como parte de un proceso (Novak y Musonda, 1991).

El *mapa conceptual* al ser insertado en procesos *heurísticos* se transforma en algo más que una forma de tomar una "nota", sino una *técnica* que puede abrir nuevas perspectivas metodológicas. El diseño de un mapa conceptual como parte de una hipótesis de trabajo podrá ir registrando en el proceso el cambio las cualidades de las relaciones, cambiando una relación hipotética por una proposición originada y argumentada en el proceso de investigación. El mapa conceptual concebido así no representará estados finales, sino intermedios y por ello mismo las relaciones entre conceptos no estarán siempre definidas o determinadas (ver figura 1.B). La ventaja de utilizar la técnica del mapa conceptual, aún y cuando no siempre se representen proposiciones, es que permite *prefigurar* la formulación de la proposición, además de que existen otros aspectos normativos que dan al sistema de representación una estabilidad para la representación y la interpretación, aún en la ausencia de la representación proposicional ya que existen otros elementos importantes que resultan estructurantes para la metodología y la investigación como son las relaciones entre conceptos y sus jerarquías.

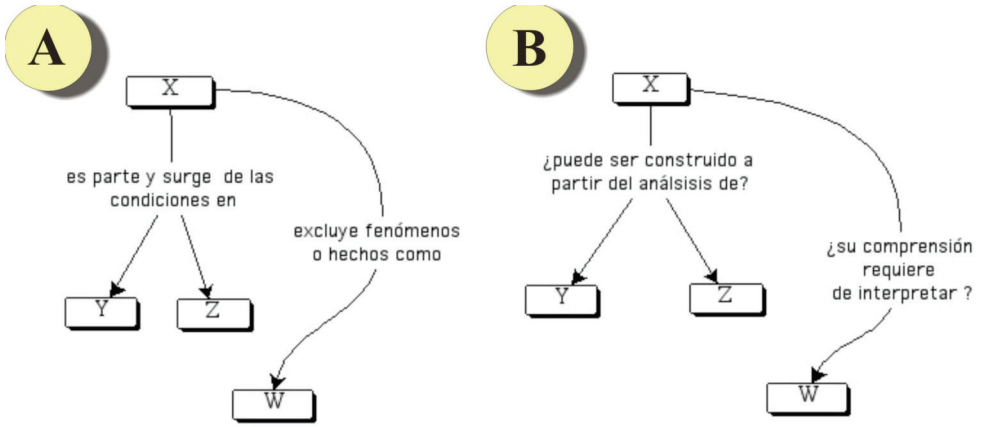


Figura 1. X, Y, Z y W son conceptos. En la estructura **A** se muestra un ejemplo modelo de algunas de las proposiciones típicas que se forman en un mapa conceptual. En el ejemplo **B** se presenta una *posibilidad* del *mapa conceptual* en un proceso de *interpretación histórica*. En dicho proceso se establecen líneas a desarrollar, y dado que ciertas proposiciones no pueden ser determinadas antes de realizar la investigación, las relaciones se convierten en *hipótesis de trabajo y estrategias metodológicas*. Las relaciones cambiarán de acuerdo al desarrollo de la investigación, pero sobre todo podrán adoptar una estructura proposicional como sugiere la técnica del mapa conceptual. En los dos casos existe una *línea narrativa*, en **A** la *narración* está "cerrada" o "fijada", mientras que en **B** *la narración* se encuentra en *construcción*. En la experiencia de los autores de este artículo, la forma de **B** permite hacer un planteamiento explícito de la construcción de categorías de análisis y los *procesos interpretativos* y una *prefiguración* de la *narración* "final". Véase un ejemplo más amplio y específico en el *mapa conceptual 1*.

4 Método y mapas conceptuales

La estructura y proceso de construcción del mapa conceptual en los ámbitos de la investigación de las ciencias sociales y humanas y en el de las ciencias naturales pueden guardar importantes diferencias. En el campo de las ciencias naturales, las representaciones intermedias podrán tener un carácter más estructurado, los *conceptos y relaciones* podrían ser "llenadas" de acuerdo a la comprobación empírica y/o formal de la hipótesis, como ejemplo y modelo paradigmático puede tomarse la tabla periódica de los elementos cuya estructura anticipó las características de ciertos elementos aún y cuando estos no habían sido descubiertos. En el caso de la *historia*, la situación es distinta, lejos de "llenar" espacios con nueva información o nuevos resultados es más probable que sean las *relaciones y estructuras* las que cambien, no por la falta de rigurosidad en el conocimiento, sino porque el establecimiento de nuevas relaciones y conceptos trae consigo la construcción de *nuevas estructuras narrativas* cuya *jerarquía conceptual* es supeditada al *sentido* del *texto* que construye el historiador. El *relato histórico* no es una versión de "lo que realmente es la disciplina de la historia", es la forma en que se construye, escribe y presenta *la historia*.

En nuestra experiencia el *mapa conceptual* permite esclarecer y profundizar en las estrategias de investigación al exponer gráficamente los elementos que el investigador ha incorporado en su análisis, el peso específico de cada uno de ellos, en la red de relaciones conceptuales y el material empírico que le permiten contrastar y validar los conceptos y las relaciones que entre ellos se utilizan, aunque ello signifique un mapa conceptual cuyas relaciones no estén por completo definidas por proposiciones (ver figura 1.B y mapa

conceptual 1). Esto permite "visualizar" el orden del conocimiento y, por lo tanto, pone de manifiesto la estructura de la representación, el discurso y la narración que subyace en él.

La capacidad del mapa conceptual para representar la *narrativa* también permite establecer líneas de investigación que serán transformadas en líneas narrativas (Aguilar Tamayo y Padilla Arroyo, 2004). El mapa conceptual integrado como parte del texto que contiene el *relato,* no sólo pasa a ser parte de la narración, sino también estructurante de narración y su lectura. Este efecto es mucho más evidente en la inserción del mapa conceptual en estructuras de hipertexto. Desde nuestra perspectiva, aplicaciones como el *CmapTools* (Cañas et al, 2004) van más allá de un soporte para elaborar, compartir y visualizar mapas conceptuales (Aguilar Tamayo, 2006), además de estructurar narrativas hipermedias (Cañas, Leake, y Maguitman, 2001), puede constituirse como un *sistema para la escritura hipertextual* (Bolter, 2001), y en caso particular que nos ocupa, un sistema para la escritura de *la narración histórica hipertextual* (Aguilar Tamayo y Padilla Arroyo, 2004; Padilla Arroyo, Aguilar Tamayo, y Nájera, 2003).

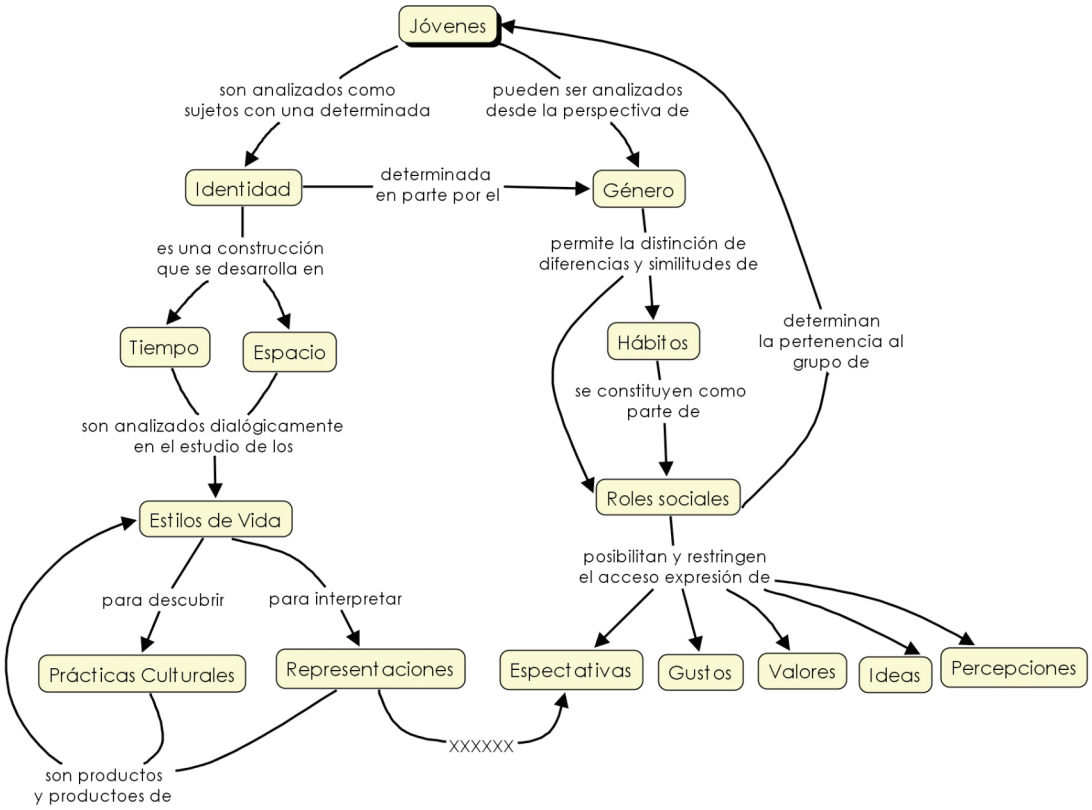
El *mapa conceptual*, junto con los instrumentos informáticos y las prácticas de una comunidad, es un sistema de escritura que produce textos, por lo que es también un modelo de comprensión y explicación de la naturaleza o del mundo social. De este modo, el *mapa conceptual*, como soporte, artefacto o dispositivo, no sólo representa conocimientos sino prácticas científicas o culturales (Aguilar Tamayo, 2006).

5 La narración histórica en los mapas conceptuales

El empleo de tecnologías como Internet y el hipertexto, en la experiencia de la investigación histórica así como en el campo de la enseñanza, han abierto nuevas alternativas para una y otra. Las ventajas y la riqueza que han aportado a la investigación histórica es amplia; acceso a la consulta y reproducción de acervos documentales, a bases de datos y bibliografía actualizada, comunicación de grupos y redes de investigadores con problemáticas similares, o para ordenar y clasificar datos, por mencionar algunas de las más significativas (Soler, 2002). Otros empleos han permitido diseñar estrategias de enseñanza, formas para organizar el conocimiento, estrategias de lectura (Biosca, Cantarell, Sancho, y Vinyoles, 2002). Todo lo anterior tiene una influencia en los cambios de las *prácticas de lectura y escritura* y sin duda en las *prácticas del historiador* (Chartier, 2000, 2002). El *mapa conceptual* y sus distintos *medios informáticos* para su elaboración y presentación lo integran a una corriente de innovación tecnológica y a un cambio en las prácticas de lectura y escritura. En la escritura de la historia, el mapa conceptual puede transformarse en una herramienta útil como parte integral de su quehacer historiográfico.

Una de las cuestiones más complejas de la historia, del pensamiento y del conocimiento, de la historiografía consiste en el cómo organizar la *trama* (Ricoeur, 1999), que va más allá de la elaboración de una cronología, o la una sucesión de acontecimientos, implica comprender, interpretar y explicar procesos, circunstancias, pensamientos, acciones, deseos, conductas, comportamientos, intenciones y sentimientos, estructuras e instituciones que, al mismo tiempo, son causas y efectos, con múltiples relaciones entre sí que el historiador selecciona y fija para decidir el contenido y la organización del relato (White, 1990).

Paul Ricoeur (1996) ha examinado con gran meticulosidad la naturaleza del conocimiento histórico y las formas en que se ordena y representa, sobre todo una de ellas; la narración. Esta contiene dos elementos fundamentales: comprender las acciones de los hombres a partir de las causas que la motivaron, *explicación por razones,* y examinar las *causas que provocaron* tal o cual acontecimiento lo que involucra un proceso de selección de los factores que lo causaron, análisis de tipo causal y un modelo nomológico. El estudio histórico busca un punto de equilibrio entre una y otra mediante el uso de conceptos y las pruebas materiales que ayuden a escribir la historia, ello implica la construcción de la trama; el ordenamiento de los conceptos, los problemas, las hipótesis de trabajo y las fuentes sobre las que operan unas y otras. Por eso, el relato o la narración "hace más que relacionar acontecimientos dentro de su aparición" e involucra frases que se emplean en pasado y enunciados irreductiblemente narrativos, es decir, un lenguaje, una disposición del pensar y del hablar. Así, parte de la especificidad del conocimiento y de la narración histórica reside en la *clase* de frases que utiliza (Ricoeur, 1996), el tiempo en que se narra la acción o hecho (Danto, 1989), e incluso cierto tipo de conectivos entre proposiciones (Van Dijk, 1989) que podrían ser más recurrentes en la narración histórica (White, 1990).



Mapa conceptual 1. Fue elaborado durante el planteamiento metodológico para el estudio de la *juventud*, en un tiempo y espacio determinado. Los conceptos de *identidad* y de *género* representan dos perspectivas analíticas así como dos perspectivas narrativas. Dado que el estudio se enmarcó en un "Instituto Científico y Literario" durante los años 1910-1920 la perspectiva de *género* no era la más apropiada puesto que en dicha institución sólo asistían estudiantes hombres. Como resulta obvio, gracias al mapa conceptual, las perspectivas analíticas también sugieren y ponen en juego conceptos y relaciones distintas. Existe una relación entre el concepto de *representaciones* y el de *expectativas* que se muestra indefinida ya que al momento de trazar la estrategia metodológica no se conocía la forma de relacionarlos y si el concepto de *expectativas* por tanto tendría una función útil en la narración histórica. El estudio histórico fue publicado por Padilla Arroyo (2004) que no sólo sigue el modelo del análisis por *identidad,* sino que en los capítulos 2 y 3 se construye una narrativa en la forma en que se muestra en el mapa conceptual. Nótese también que varias de las relaciones proposicionales siguen la *intención investigativa* y no una relación ya determinada, por ejemplo: "**Tiempo** y **Forma** *son analizados dialógicamente en el estudio de los* **Estilos de Vida**". El mapa conceptual en su generalidad es el planteamiento de la pregunta-hipótesis ¿quiénes son los jóvenes y porqué lo son? ¿Cómo se es joven?

Hayden White (2001) ha destacado la naturaleza de la obra histórica, definiéndola como "una estructura verbal en forma de discurso en prosa narrativa" que combina varios elementos, entre ellos cierta cantidad de datos, conceptos teóricos, que ayudan a explicar, esto es, a convertir los datos en hechos históricos, las relaciones que contienen y una estructura narrativa mediante los cuales se presentan como "la representación de acontecimientos que *supuestamente* ocurrieron en el pasado" (cursivas de los autores), la narración dota al discurso histórico de un "contenido estructural".

El historiador tiene distintas posibilidades para articular tramas y narraciones que operan de manera implícita, sea provocado por el *habitus* o por *formas culturales* de interpretación arraigadas en la construcción e interpretación de los relatos (Wertsch, 1998). El proceso de la investigación y la producción de la narrativa histórica conducen a la toma de conciencia de la representación que hace el historiador (o al menos eso debería ocurrir), en este proceso nos parece que el mapa conceptual tiene mucho que aportar. La visualización de la *trama histórica* y la *red de relaciones* expresada con un cierto orden y estructura a través de las relaciones y la jerarquía, prefiguran al texto a construir, permite imaginar o visualizar la narrativa en construcción. Lo anterior puede explicarse a través del ejemplo que se presenta en el *mapa conceptual 1*.

El *mapa conceptual 1* fue elaborado para determinar la metodología de un estudio historiográfico que buscaba, a través del concepto de *juventud*, dar respuestas a preguntas más específicas sobre el "Instituto Científico y Literario del Estado de México" considerado como "un buen ejemplo, naturalmente con las

limitaciones y alcances propias de su espacio y tiempo, de uno de los establecimientos más representativos de la cultura y la ciencia del país" (Padilla Arroyo, 2004, p.13). Aunque el estudio resulta más amplio y no se limita a la *juventud*, es a través de la vida los "jóvenes" en el Instituto que se indagan distintos aspectos de la organización, filosofía y normatividad de la institución (p. 15).

En el ejemplo que se muestra (mapa conceptual 1), existen dos perspectivas analíticas, una que se establece a partir del concepto de *identidad* y la otra desde el concepto de *género*. La perspectiva que tomó la investigación historiográfica realizada (Padilla Arroyo, 2004) fue la de *identidad*, la perspectiva de género resultaba inaplicable debido a que el tiempo en que se acota el estudio los alumnos del instituto eran solamente hombres. A partir de los conceptos de *identidad* y el de *género* no sólo se plantea una semántica conceptual y teórica sino una estrategia narrativa. La estructura narrativa de la investigación es su forma final, retomó la estructura del mapa conceptual, principalmente en los capítulos 2 y 3, en ese sentido el mapa conceptual sirvió para prefigurar y estructurar la narrativa a construir y por tanto también el conocimiento histórico.

Fabricar y escribir el texto significa organizar los datos y los conceptos, la red de relaciones entre unos y otros, precisar sus significados, fijar el encadenamiento lógico y, de esta manera, interpretar, explicar y conocer la realidad. El pensamiento histórico es la representación del pasado histórico y su materialidad puede traducirse en diversos soportes, especialmente el texto impreso porque está ha sido la manera más usual de comunicar sus resultados. La *narración histórica* es una vía posible para hacer comprensible el pasado porque pretender fijar y acotar una explicación, una interpretación, pero no es la única ni la más verdadera porque la calidad, la particularidad, la materia misma de historia sólo puede conocerse mediante aproximaciones.

6 Conclusiones

El *mapa conceptual* puede ocupar un lugar fundamental dentro de la *narración histórica* y constituirse en un modo de acceso al conocimiento histórico y legitimarse y validarse ante la comunidad académica. En efecto, el *mapa conceptual* puede transformarse en un soporte para la construcción del conocimiento histórico, en un medio y no un fin. El asunto de la validez y de la legitimidad de la narración no depende del uso correcto o incorrecto del *mapa conceptual* sino de los procesos de construcción de la narración. En otras palabras, su importancia como herramienta para establecer y fijar la narración histórica debe ser establecida por el trabajo del historiador. Es una herramienta que genera estrategias para construir un saber o conocimiento porque contiene instrumentos que lo posibilitan; por una parte, al brindar un soporte técnico, el software (*CmapTools*, Cañas et al., 2004) que permite fijar con claridad los recursos teóricos y metodológicos, así como documentales de que se vale el historiador para fabricar sus relatos, independientemente de la naturaleza y los alcances de los documentos escritos, de las imágenes, entre otros. Por otra parte, el ambiente hipertextual permite ordenar y presentar tramas narrativas que tal vez el autor no había imaginado al estar en condiciones de leer de manera simultánea no sólo conceptos y sus relaciones, sino procesos, estructuras y actores que simultáneamente están en circunstancias, espacios y tiempos diversos y múltiples pero que enlazadas entre sí y que el autor tiene que demostrar cómo y porqué se hayan en esa condición.

7 Referencias

Aguilar Tamayo, M. F. (2004). El Mapa Conceptual: Un texto a interpretar. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, España: Universidad Pública de Navarra.

Aguilar Tamayo, M. F. (2005). Representaciones visuales-conceptuales del conocimiento y estructura del hipermedia educativo. Tesis no Publicada Type, Univ. Autónoma del Estado de Morelos, Cuernavaca, México.

Aguilar Tamayo, M. F. (2006). Origen y destino del mapa conceptual. Apuntes para una teoría del mapa conceptual. En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. of the 2nd International Conf. on Concept Mapping*. San José, Costa Rica: Univ. de Costa Rica.

Aguilar Tamayo, M. F., & Padilla Arroyo, A. (2004). La Narración en los Mapas Conceptuales. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First Int. Conf on Concept Mapping*. Pamplona, España: Univ. Pública de Navarra.

Biosca, E., Cantarell, E., Sancho, M., & Vinyoles, T. (2002). Reconstruyendo el pasado. Enseñar con tecnologías de realidad virtual. Iber. Didáctica de las Ciencias Sociales, Geografía e Historia, VIII(31), 103-110.

Bolter, J. D. (2001). Writing Space. Computers, Hypertext and the Remedation of Print. USA: Lawrence Erlbaum Associates, Publishers.

Bourdieu, P. (2003). Cuadernos de Sociología. España: Ediciones Istmo, S. A.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology*. *Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cañas, A., Leake, D., & Maguitman, A. (2001). Combining Concept Mapping with CBR: Towards Experience-Based Support for Knowledge Modeling.Retrieved 28, marzo, 2005, from www.aaai.org

Chartier, R. (2000). Las revoluciones de la cultura escrita. Diálogo e invenciones. España: Gedisa.

Chartier, R. (2002). El mundo como representación. Historia cultural: entre práctica y representación. España: Gedisa.

Danto, A. C. (1989). Historia y narración. Ensayos de filosofía analítica de la historia. España: Paidós.

Gadamer, H. G. (1994). Fundamentos para una teoría de la experiencia hermenéutica. En: A. Mendiola Mejía (Ed.), Introducción al análisis de fuentes (pp. 130-147). México: Universidad Iberoamericana.

John-Steiner, V. (1997). Notebooks of the Mind. USA: Oxford University Press.

Locke, D. (1997). La ciencia como escritura. España: Cátedra.

López Serra, A. (2002). Jugar, debatir, conspirar. Medios tecnológicos y fines educativos en la enseñanza de las ciencias sociales. Iber. Didáctica de las Ciencias Sociales, Geografía e Historia, VIII(31), 50-62.

Novak, J. D. (1998). Conocimiento y aprendizaje. Los mapas conceptuales como herramientas facilitadoras para escuelas y empresas. Madrid: Alianza.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. American Educational Research Journal, 28(1), 117-153.

Padilla Arroyo, A. (2004). Tiempos de revuelo: juventud y vida escolar. El instituto Científico y Literario del Estado de México (1910-1920). México: Miguel Ángel Porrúa.

Padilla Arroyo, A., Aguilar Tamayo, M. F., & Nájera, E. I. (2003). Interpretations of Historical Sources: From the Narrative of History to the Hypertextual Discourse. En: A. Méndez-Vilas & J. A. Mesa Gonzáles (Eds.), Advances in Technology-based Education: Towards a Knowledge-based Society. España: FORMATEX.

Ricoeur, P. (1996). Tiempo y narración. La configuración del tiempo histórico (Vol. I). México: Siglo XXI.

Ricoeur, P. (1999). Para una teoría del discurso narrativo. En: Á. Gabilondo & G. Aranzueque (Eds.), Paul Ricoeur. Historia y narratividad (pp. 83-155). España: Paidós.

Soler, J. (2002). Nuevos medios, investigar y publicar historia hoy. Iber. Didáctica de las Ciencias Sociales, Geografía e Historia, VIII(31), 33-49.

Van Dijk, T. A. (1989). Estructura y funciones del discurso (6a ed.). México: Siglo XXI.

Viñao Frago, A. (1999). Leer y escribir. Historia de dos prácticas culturales. México: Fundación Educación, voces y vuelos IAP.

Wertsch, J. V. (1985). Vygotsky and the Social Formation of Mind. Cambridge: Harvard University Press.

Wertsch, J. V. (1998). Mind as Action. USA: Oxford University Press.

White, H. (1990). The content of the Form. Narrative Discourse and Historical Representation. USA: The John Hopkins University Press.

White, H. (2001). Metahistoria. La imaginación histórica en la Europa del siglo XIX. México: Fondo de Cultura Económica.

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EL MAPA CONCEPTUAL Y LA TEORÍA SOCIOCULTURAL

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Abstract. Joseph Novak ha destacado el concepto de *zona de desarrollo próximo* (ZDP) como una forma de comprender y orientar el diseño de procesos de enseñanza y aprendizaje. A partir de estas observaciones, el presente artículo explora algunos puntos de encuentro de Novak con la teoría de Vygotski. Se aborda el concepto de ZDP y otros más como son: el de *mediador y artefacto cultural*, conceptos que resultan indispensables en el marco de la teoría sociocultural para comprender el concepto de ZDP y para explicar el lugar del mapa conceptual en la teoría sociocultural. El estudio de las funciones del mapa conceptual desde esta perspectiva requiere de tomar en cuenta el *sistema de actividad* en el cual participa. Este trabajo pretende poner en la mesa de la discusión conceptos originados por la teoría sociocultural y que resultan útiles para comprender y construir una *teoría del mapa conceptual*. Este artículo utiliza el mapa conceptual como parte integral de la exposición y la discusión, por lo que son parte de los contenidos y permiten representar de manera más sintética la complejidad los conceptos que se tratan.

1 Novak y sus acercamientos a la teoría de Vygotski

La teoría sociocultural ofrece conceptos útiles para el análisis del hecho educativo. Recientemente Novak ha llamado la atención sobre uno en especial, la *zona de desarrollo próximo* (Novak, 2002, p.551, 2004, p.464; Novak y Cañas, 2004, p.471), concepto formulado por Vygotski (1979; 2001; 1995) fundador de la corriente sociohistórica en la psicología rusa y cuyos conceptos han sido atraídos por la psicología cultural norteamericana y otras corrientes socioculturales que no sólo incluyen la psicología sino se extienden a la antropología, educación, sociología e historia, por mencionar algunas (Cole, 2000).

Aunque la referencia al concepto de zona de desarrollo próximo es reciente en Novak, el interés por otros aspectos de la teoría vygotskiana pueden observarse años atrás. En *A Theory of Education*, publicado en 1977, Novak menciona que tanto él como Ausubel reconocen el papel fundamental que tiene el lenguaje para el *desarrollo cognitivo*, posición que los acerca al pensamiento de Vygotski (Novak, 1982, p.113). Otro punto de encuentro de Novak con la teoría de vygotskiana es respecto al papel del aprendizaje escolar y la incidencia de este en el desarrollo cognitivo (Novak, 1998, p.69). El *concepto* y la *palabra* son conceptos diferenciados por los tres autores, Novak y Ausubel coinciden con Vygotski en que la *palabra* sirve como un medio para la formación del *concepto* (Ausubel, 2002, p.31; Novak, 1998, p.58; Vygotski, 2001, pp.121, 131).

Novak advirtió el valor de las ideas de Vygotski para la educación (Novak, 1982, p.114), algunas de ellas valiosas para interpretar e intervenir en los nuevos hechos educativos, un ejemplo de ello son las estrategias de *trabajo colaborativo* (Novak, 2004, p.464), aspecto importante puesto que la *colaboración* y el conocimiento compartido es uno de los principios de diseño del *CmapTools* (Novak y Cañas, 2004, p.469), herramienta que es parte de las prácticas que involucran al mapa conceptual.

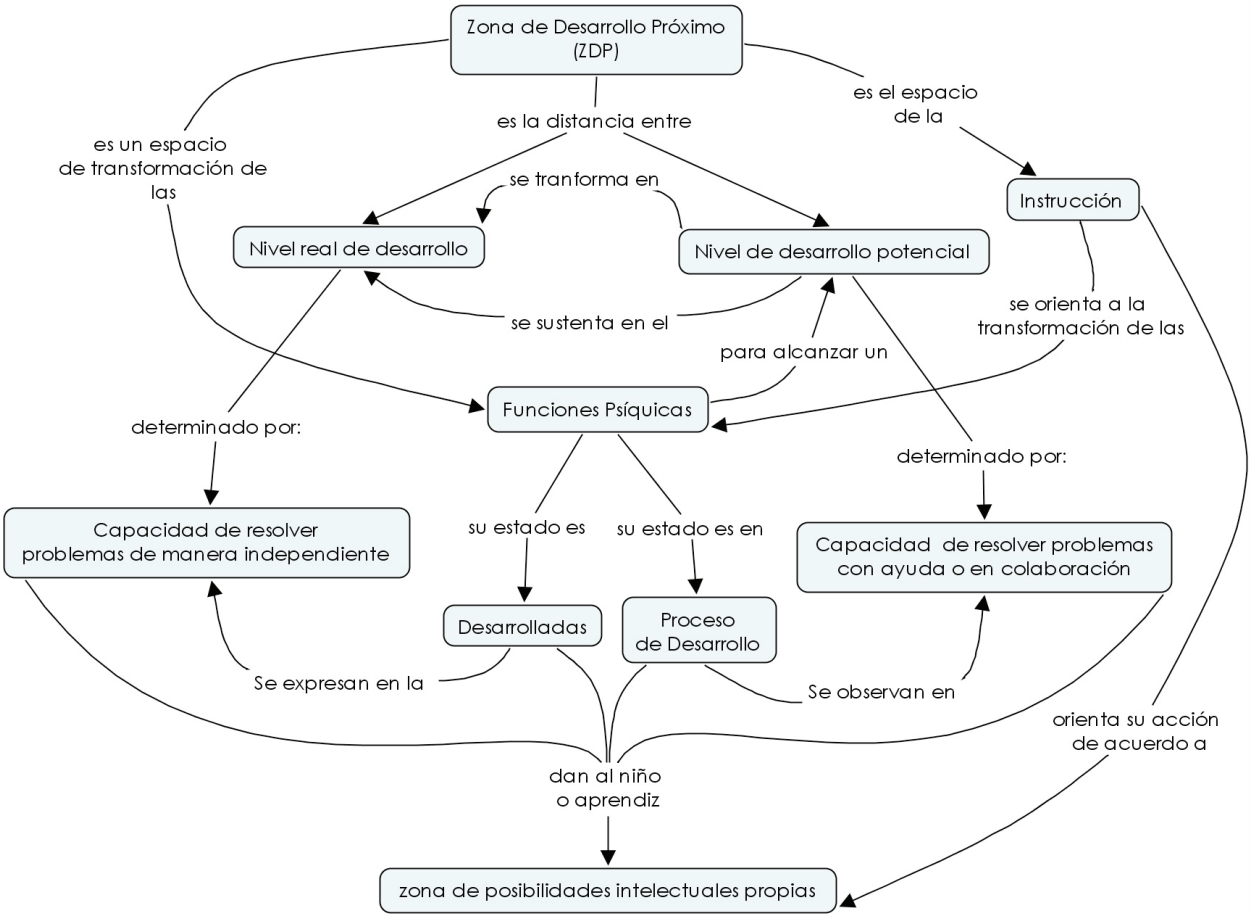
El concepto de zona de desarrollo próximo le ha permitido a Novak reinterpretar o redescribir acciones realizadas anteriormente aún cuando estas no manifestaran explícitamente un contexto teórico vygotskiano (Novak, 2004, p.465). Los encuentros teóricos entre Novak y Vygotski se deben mucho al interés por lo educativo y a la forma en que los autores comprende los propósitos de la enseñanza y sus efectos en las estructuras cognitivas de los sujetos. El concepto de *zona de desarrollo próximo* permite el análisis conjunto de conceptos como *enseñanza e instrucción*, *actividad mediada, lenguaje y aprendizaje*, permite por tanto observar el hecho educativo como un arreglo complejo de actores, instrumentos y conocimiento.

2 El concepto de zona de desarrollo próximo

El concepto de *zona de desarrollo próximo* (de ahora en adelante ZDP) ha permitido, además de replantear el hecho educativo y su significado en el desarrollo psíquico en el sujeto, destacar en el análisis otros agentes de

la educación como son: el *maestro, compañeros o pares* y los *instrumentos culturales* cuya función *mediadora* en los aprendizajes cobran significado gracias al concepto de *ZDP*.

En el mapa conceptual 1 se presenta una reconstrucción del concepto de *ZDP* a partir de tres textos de Vygotski, dos de ellos son versiones distintas de su libro *Pensamiento y Lenguaje* (Vygotski, 2001; Vygotsky, 1995), la tercera obra es el *Desarrollo de los procesos psicológicos superiores* (Vygotski, 1979).



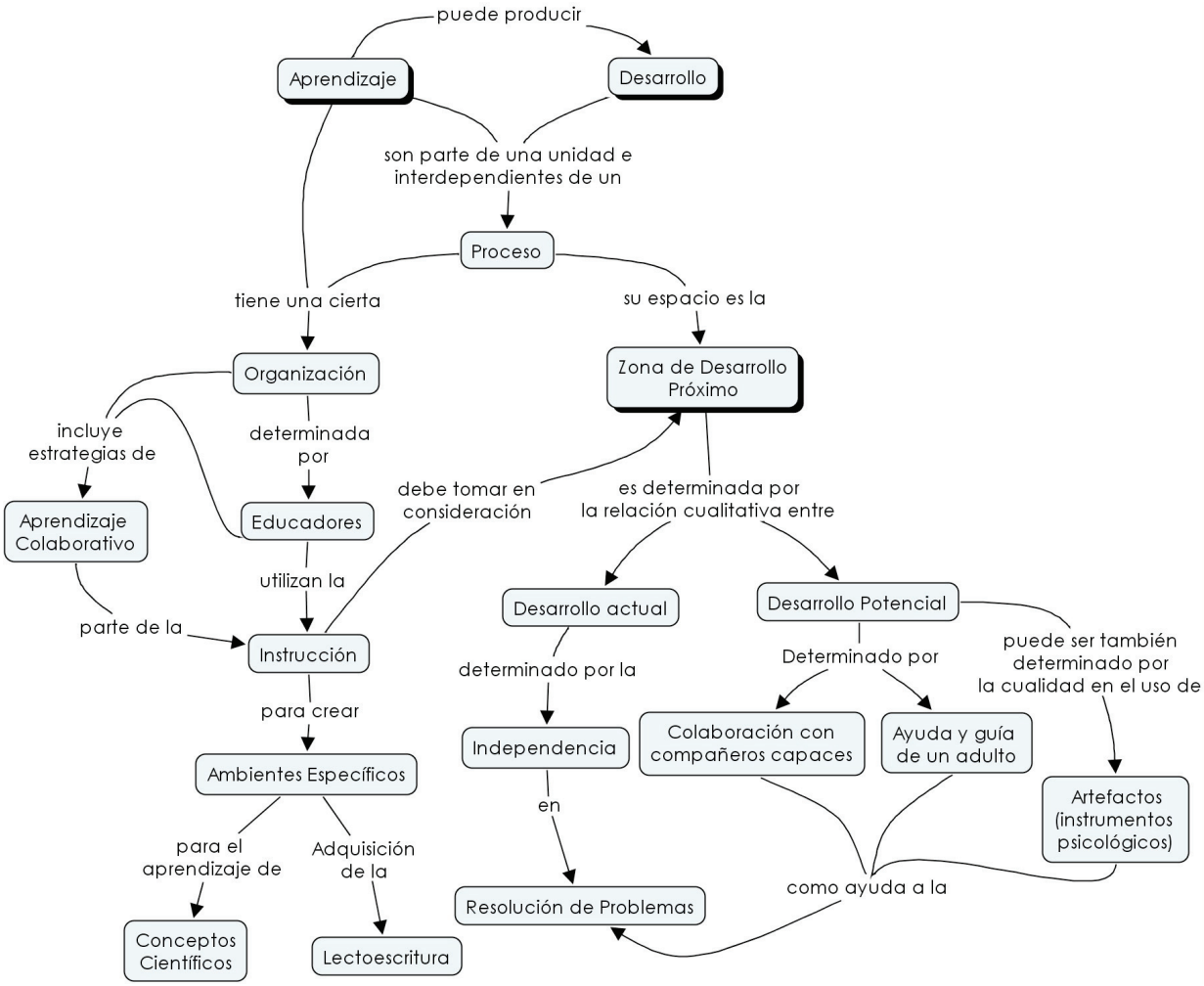
Mapa conceptual 1. Elaborado a partir del libro de *Pensamiento y Lenguaje*, en dos de sus versiones (Vygotski, 2001; Vygotsky, 1995) y el libro de *El desarrollo de los procesos psicológicos superiores* (Vygotski, 1979). El mapa conceptual presenta el concepto de ZDP desde la perspectiva de *Pensamiento y Lenguaje*, el concepto es planteado por Vygotski después de una discusión acerca de la formación de conceptos científicos y el papel de la escuela en el aprendizaje de estos. En el libro de *El desarrollo de los procesos psicológicos superiores* se aborda primero el concepto de *desarrollo* para después tratar el de *zona de desarrollo próximo*. En *teoría del desarrollo* de Vygotski confluyen y se articulan gran parte de los conceptos desarrollados por dicho autor.

El concepto de *ZDP* debe abordarse desde un contexto dinámico de *enseñanza-aprendizaje-desarrollo* para comprender los efectos que la educación escolar tiene en el *desarrollo*. El mapa conceptual 1 no refleja el análisis de Vygotski respecto al papel de la instrucción y la promoción de cierto tipo de aprendizajes que pueden derivar, en ciertas circunstancias, en *desarrollo* (Aguilar Tamayo, 2004a; John-Steiner y Mahn, 1996; Vygotski, 1979, p.139).

Vygotski expone el concepto de *ZDP* de dos formas. En *Pensamiento y Lenguaje*, lo aborda después de una discusión amplia del proceso de formación de conceptos científicos en el niño, destaca el valor de la instrucción para provocar desarrollo intelectual en el niño, la mayor parte de este capítulo (Vygotski, 2001, Cap. 6, p.181-285; Vygotsky, 1995, Cap. 6, p.153-196) y el anterior, la discusión se centra en el aprendizaje de conceptos y las características de los conceptos científicos; jerarquía y estructura, por mencionar dos de ellas (Vygotsky, 1995, p. 170). En el caso del texto de *Los procesos psicológicos superiores*, el planteamiento del concepto de ZDP deriva de una exposición detallada del proceso de desarrollo de las *funciones*

psicológicas superiores y la función del *signo* (lenguaje, escritura, gráficos) como *mediadores* para el control de las *funciones psicológicas elementales*, y la construcción de las funciones psicológicas superiores a partir de la *interiorización* del signo. En el mapa conceptual 2, se presenta una visión más global del concepto de ZDP y permite entender de mejor forma la unidad dialéctica de *aprendizaje y desarrollo* y cómo ubicar y estudiar los procesos que se dan en esa unidad dialéctica a partir del concepto de ZDP. Estas dos aproximaciones ponen en relieve la complejidad del concepto de ZDP cuya función es delimitar un campo de acción didáctica o de la actividad, así como descubrir o construir un momento para observar el proceso en el desarrollo, entendido este como un proceso de aprendizaje-instrucción que conlleva a la transformación o creación de las funciones psicológicas superiores.

En el mapa conceptual 2 se expone el proceso de *organización de la educación y el proceso de aprendizaje* como formas de producir el desarrollo, se ha realizado basado en las ideas de John-Steiner y Mahn (1996) con respecto a las ideas de Vygotski.



Mapa conceptual 2. Elaborado a partir de John-Steiner y Mahn (1996), se muestra el contexto en el cual surge el concepto de Zona de Desarrollo Próximo y sus relaciones con el proceso de instrucción y otros *agentes activos* cuya función es la de ser *mediadores* en los procesos de aprendizaje, tal es el caso de los *compañeros*, *adultos y maestros* y el uso de *artefactos*, entre los cuales puede considerarse el mapa conceptual.

El concepto de ZDP ofrece un modelo de articulación entre la teoría cognitiva y la de la enseñanza, es por esta razón que resulta complementaria a la perspectiva de Novak cuyo desarrollo conceptual cruza constantemente las fronteras de lo psicológico y lo educativo.

3 El mapa conceptual un nuevo objeto de investigación y nuevas perspectivas para su investigación

El mapa conceptual como técnica de investigación (Novak y Musonda, 1991) y su transformación en una herramienta para la enseñanza y aprendizaje (Novak y Gowin, 1988) ha mantenido estrecha relación con la teoría del aprendizaje significativo de Ausubel (2002). En dicho contexto de origen, el mapa conceptual no fue planteado de manera explícita como *un objeto de estudio* sino como un recurso didáctico y una técnica y metodología para investigar el cambio de estructuras cognitivas en los alumnos. La expansión de la técnica ha dado lugar a un cambio en el uso y aplicación del mapa conceptual ampliando el debate a otros campos y teorías, las comunidades de investigación y educación ponen el interés *en el mapa conceptual* convirtiéndolo en un objeto de estudio en sí mismo (Aguilar Tamayo, 2006). La estabilidad de la técnica y su uso extendido, le da un lugar como parte de los recursos culturales y sociales para la representación, preservación y construcción del conocimiento. De esta forma, para una parte importante de la comunidad educativa, el mapa conceptual llega a su conocimiento y a sus prácticas como una *técnica de representación* a lado de otras como son: diagramas, tablas y esquemas, entre otras (Aguilar Tamayo, 2005).

La distinción entre la técnica y la teoría del mapa conceptual permite considerarlo como un sistema de representación autosuficiente (Aguilar Tamayo, 2005), así la lectura del mapa conceptual es factible aún en la ausencia de conocimiento sobre la teoría que lo sustenta y de igual forma es posible su elaboración (Aguilar Tamayo, 2004b, 2006). El saber sobre la técnica permite la escritura del mapa conceptual, el conocimiento *sobre la técnica* es parte de una *teoría*. Puede hacerse una analogía con la escritura; saber leer y escribir es distinto a saber y conocer sobre el acto de leer y escribir, el segundo caso es parte de un conocimiento especializado originado en una teoría o disciplina, como por ejemplo la lingüística.

El interés de descontexualizar el mapa conceptual, es decir, de separar la técnica de la teoría, no radica en eliminar su referente y menos aún sustituirlo, es más bien una estrategia para reconstruirlo conceptualmente como objeto de investigación, y con ello presentarlo como un *objeto* visible desde otras perspectivas teóricas. De esta forma es posible comprender el mapa conceptual, desde la teoría sociocultural, como un *artefacto cultural* cuyas funciones *mediadoras* son parte de un sistema de actividad orientado para provocar ciertas conductas y procesos en el espacio de oportunidades reconocido como *zona de desarrollo próximo*.

Novak diseñó un modelo educativo en el marco de un programa de investigación (Novak y Musonda, 1991), este modelo funcionó como un estímulo controlado para provocar en los alumnos cambios en su estructura cognitiva que en el plano educativo significaba el aprendizaje de conceptos científicos. El experimento logró demostrar que la *construcción de nuevos significados* es el proceso mediante el cual se logra el aprendizaje de conceptos científicos, entre otros hallazgos, que no pueden discutirse en este momento. En artículos posteriores al reporte de la investigación ya citado (Novak y Musonda, 1991), Novak recupera el concepto de ZDP para interpretar lo ocurrido en el *proceso de construcción de significados* y entender el éxito de las lecciones diseñadas para el proyecto de investigación realizado años antes, aunque el párrafo que se cita a continuación se refiere a un *modelo instruccional*, no debe olvidarse que los mapas conceptuales son parte de actividades realizadas en ese contexto y que pueden formar parte de las estrategias que se mencionan:

> A pesar de que no estábamos conscientes de las ideas de *andamiaje* y la *ZPD* al momento del diseño de las audio-lecciones tutoriales hicimos cosas congruentes con esas ideas. Para el diseño de dichas lecciones, entrevistamos a niños para observar qué pensaban acerca de un concepto o problema en particular para, posteriormente, diseñar experiencias que permitieran construir sobre lo que ellos sabían y para que pudieran ampliar sus ideas al respecto, para ello se brindaron experiencias de trabajo directo con materiales y el vocabulario científico para explicar los eventos que los alumnos observaban. Es posible que las breves experiencias instruccionales de los niños con las lecciones audio-lecciones tutoriales en los grado uno y dos, tuvieran un impacto sostenido en posteriores aprendizajes de las ciencias debido a que estábamos en la dirección correcta, trabajando *en* la ZDP de los niños, utilizando las actividades y el lenguajes apropiados creando un "andamiaje" para su aprendizaje (Texto original en inglés) (Novak, 2004, p.465)

En otro artículo de Novak y Cañas (2004) se recupera de manera específica la función del mapa conceptual como ayuda al alumno para el aprendizaje, los autores destacan que esta función, entre otras, son

soportadas por ideas de Vygotski, entre ellas la de ZDP, el *trabajo colaborativo* y el *contexto sociocultural* que rodea a estos:

> Las experiencias de Novak en el uso de mapas conceptuales como ayuda y guía al aprendizaje de los estudiantes han sido altamente positivas. Estas están soportadas en las ideas de Vygotski (1928, 1978) [1979] sobre la importancia del intercambio cultural en el aprendizaje. Otro concepto de Vygotski, que apoya dichas experiencias, es el de "Zona de Desarrollo Próximo" (ZDP). Los estudios de Vygotski mostraron que existe un nivel de desarrollo cognitivo que permite al aprendiz avanzar en el entendimiento de un determinado dominio de conocimiento de manera independiente y que hay también un nivel superior de entendimiento en el cual el aprendiz no puede avanzar sin ayuda. Vygotski llamó a este rango de entendimiento la zona de desarrollo próximo. Una ventaja del aprendizaje colaborativo es que los estudiantes tienden a estar en la misma ZDP, de ahí que pueden comunicarse entre ellos sus propias ideas de una mejor forma. Cuando los alumnos son asistidos por un mapa conceptual con "estructura experta" pueden progresar todavía más. En general la literatura sobre el "acompañamiento" de estudiantes tiene varias aproximaciones y muestra que el acompañamiento facilita de manera significativa el aprendizaje (Bransford, Brown y Cocking, 1999). Dado que la facilitación del aprendizaje es posible utilizando CmapTools, las ideas de Vygotski resultan de gran utilidad, así como otras ideas en la literatura acerca del acompañamiento, para ser incorporadas a la instrucción (Texto original en inglés) (Novak y Cañas, 2004, p.471)

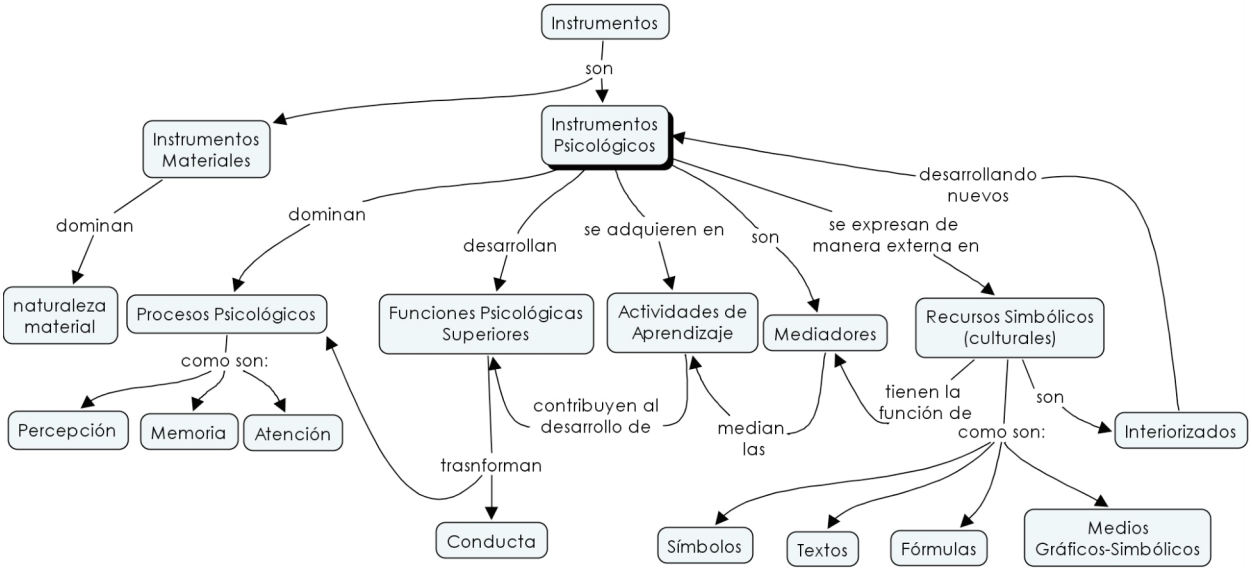
El *CmapTools* (Cañas et al., 2004) y el mapa conceptual, se constituyen como objetos cuyas funciones, tal como se aprecia en la cita anterior, pueden ser entendidas desde la perspectiva constructivista y la sociocultural, representada esta última por las ideas de Vygotski. Es importante destacar que Novak y Cañas (2004) proponen a las funciones de CmapTools y las funciones del mapa conceptual junto con la teoría educativa de Novak, como los articuladores de un modelo educativo; de esta manera el complejo *mapa conceptual-CmapTools* es una *práctica* que va más allá de la elaboración del mapa conceptual, es un proceso que implica estrategias sobre colaboración y actitudes frente al conocimiento (Aguilar Tamayo, 2006).

El concepto de ZDP trae consigo otros más que permiten explicar los procesos de construcción de significados. El "acompañamiento" y la función de la "estructura experta", desde la perspectiva sociocultural, son intervenciones semióticas que pueden ser estructuradas por agentes humanos o artefactos, como el texto, audio-lecciones tutoriales y los mapas conceptuales; son intervenciones que cumplen la función de *mediadores* para el aprendizaje y hacen uso de distintos *artefactos culturales* (texto, esquemas, mapas conceptuales, lenguaje), para comunicar y *mediar* (ayudando o colaborando) la *actividad de aprendizaje* (Aguilar Tamayo, 2003). En el mapa conceptual 2, presentado anteriormente, puede observarse la función de los *artefactos o instrumentos psicológicos* en el proceso de aprendizaje en al ZDP.

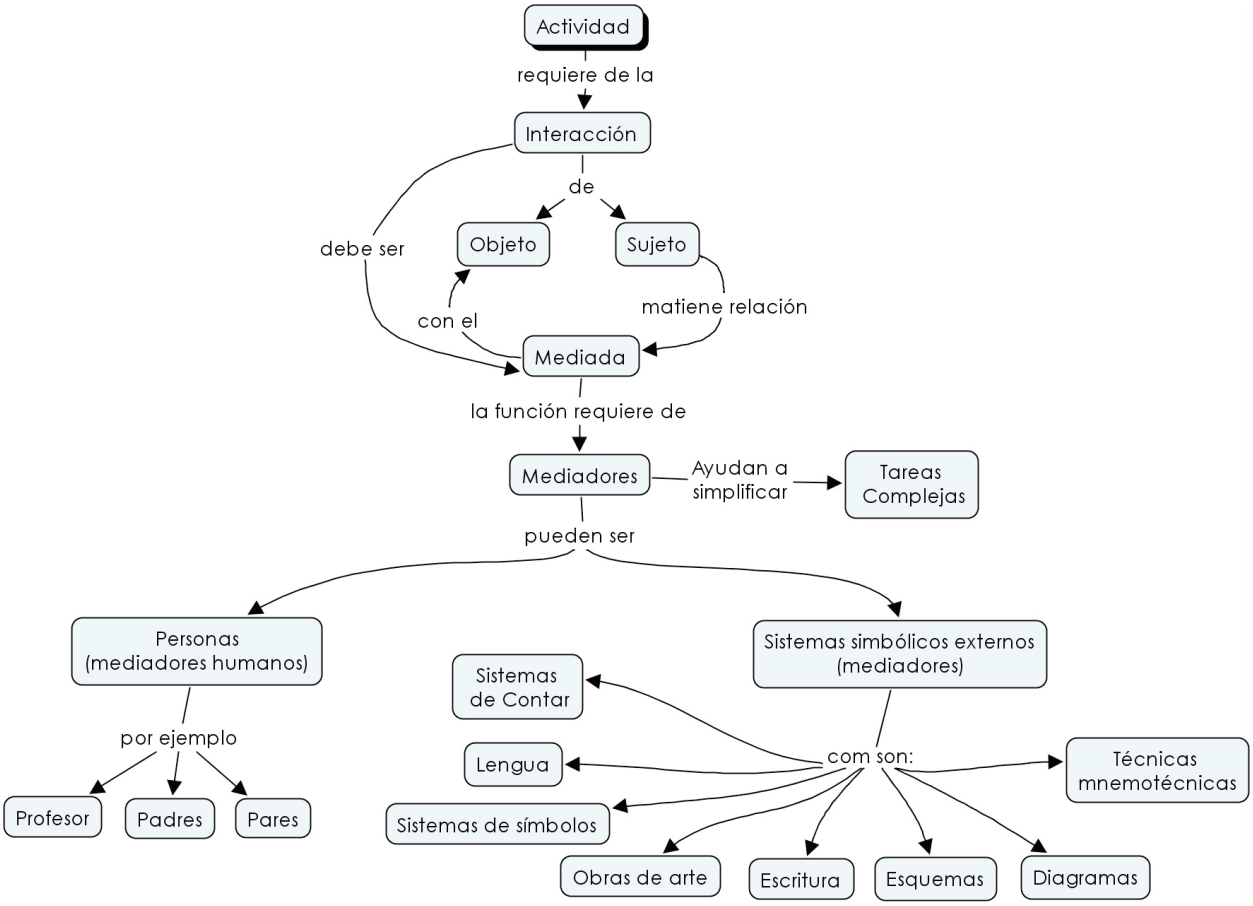
4 El mapa conceptual, un artefacto cultural

Las ideas de Vygotski y sus conceptos han tenido un impacto amplio, las distintas traducciones y enfoques han dado origen a distintos *términos* que ponen énfasis en uno u otros aspectos de la teoría vygotskiana, así términos como *artefacto cultural* (Cole, 2000; Daniels, 2003)*, herramientas culturales* (Wertsch, 1998) *herramientas simbólicas* (Rivière, 2002)*, signo, instrumento psicológico o instrumentos para el pensamiento* (Kozulin, 2000; Vygotski, 1979; Wertsch, 1985) y otros más, son conceptos que se refieren a los mismos hechos y objetos que generalmente son referidos por Vygotski como *signos o instrumentos psicológicos*, ejemplos de estos son: el lenguaje, formas de numeración, dispositivos mnemotécnicos, algebra, obras de arte, escritura, diagrama, mapas, dibujos y otros signos convencionales (Vygotski, 1997, p. 65).

La importancia del *signo o instrumento psicológico* radica en su *función mediadora para el pensamiento* y la transformación y desarrollo de las *funciones psíquicas superiores*, tales como la memoria lógica, pensamiento verbal y la atención voluntaria (Vygotski, 1979, 1995). Para Vygotski el proceso de maduración trae consigo el desarrollo de ciertas funciones llamadas *naturales* como son: la *memoria, la atención y la percepción* (Kozulin, 2000). La diferencia entre las funciones *superiores* con respecto a las *naturales* o *elementales*, es el uso de *medios externos*, algunos de ellos *interiorizados* para ser utilizados como estímulos.



Mapa conceptual 3. Perspectiva de Kozulin (2000) sobre las funciones de los *instrumentos psicológicos*. Se inicia con el concepto de *instrumento* porque Vygotski parte de la analogía de los *instrumentos materiales,* que transforman la naturaleza y por tanto median la actividad del hombre en los procesos de transformación de ella, y los *instrumentos psicológicos*, que sirven para actuar *internamente* y no *externamente*, controlando y transformando los procesos psicológicos (Vygotski, 1979, 1995).



Mapa conceptual 4. La función de los *mediadores* sólo puede comprenderse en un sistema de *actividad*. Este mapa conceptual fue elaborado a partir de Daniels (2003) y la función de los mediadores depende en gran parte de la forma en que se plantea la actividad del sujeto, el énfasis en la *actividad mediada* como unidad de análisis se encuentra en otros autores como Wertsch (1985; 1993).

internos (Rivière, 2002) y controlar las funciones naturales, creando así un nuevo sistema que da lugar a la constitución de las funciones psicológicas superiores. La *memoria lógica* es una transformación de la *memoria natural* en cuanto que el recuerdo es *voluntario* y *mediado* por el lenguaje o el uso de otros medios como notas, o técnicas mnemotécnicas

En el mapa conceptual 3 se presenta la perspectiva de Kozulin (2000) sobre la función mediadora de los instrumentos psicológicos y en el mapa conceptual 4 se presentan las funciones de mediación originadas de la *actividad*. Las funciones del instrumento psicológico pueden variar de acuerdo al sistema de actividad en el que se vea implicado. El mapa conceptual, considerado como un artefacto cultural o *sistema de representación externa* (Aguilar Tamayo, 2004b, 2005) puede también considerarse como un *recurso simbólico* (véase mapa conceptual 3) y un *sistema simbólico externo* (véase mapa conceptual 4), conceptos equivalentes al de *signo* en Vygotski.

5 Conclusiones

El mapa conceptual es un instrumento cultural cuyas funciones mediadoras dependen del sistema de actividad en el que participe. Las funciones pueden darse en distintos niveles y pueden explicarse desde los conceptos de *funciones psíquicas, desarrollo y mediador semiótico*. El lugar, espacio o función del mapa conceptual no es estático en la zona de desarrollo próximo, algunas de sus características estarán marcadas por sus características funcionales, es decir, por la *técnica*, otras dependen del arreglo de la actividad en la que sea utilizada la herramienta. No es posible en este espacio tratar de manera más amplia los posibles sistemas de actividad que involucran al mapa conceptual, es una tarea pendiente y que deberá ser retomada por la comunidad educativa y de investigación en el cuadro analítico de la *zona de desarrollo próximo*.

Reconocido el mapa conceptual como una artefacto cultural, el proceso de apropiación de la herramienta puede ser examinado junto a otras herramientas culturales que conjuntamente son el *kit* de *recursos culturales* (Pozo, 2003) de los que se disponen socialmente para la representación, preservación y construcción del conocimiento, deja de ser en ese sentido, un objeto particular para ser un objeto cultural, cuyas funciones, además de las técnicas, son social y culturalmente definidas de la misma forma que ocurre con la pintura, la literatura, el lenguaje, el cine y otras formas representacionales.

Este trabajo es una forma de abordar el mapa conceptual *desde* la mirada de la teoría sociocultural, se ha evitado la *suplantación* del sustento teórico, es decir, no se han confrontado los supuestos teóricos de la teoría del aprendizaje significativo de Ausubel con respecto a la teoría sociocultural, la razón de ello se encuentra en la diversidad y amplitud de las prácticas del mapa conceptual que van más allá de estas dos formas de abordar el problema de la instrucción y el aprendizaje y además que el análisis puede plantarse también en los encuentros entre Novak, Ausubel y Vygotski en la forma de concebir el concepto científico y la organización y jerarquía de estos (Aguilar Tamayo, (en prensa); Pozo, 1994).

6 Referencias

Aguilar Tamayo, M. F. (2003). A model of Educational Hypertext taken from Vygotsky's Theorical Perspective. En: A. Méndez-Vilas & J. A. Mesa Gonzáles (Eds.), *Advances in Technology-based Education: Toowards a Knowledge-base Society*. España: FORMATEX.

Aguilar Tamayo, M. F. (2004a). El concepto de desarrollo en Vygotski como marco de reflexión para el uso de tecnologías en la enseñanza y aprendizaje en personas con discapacidad. *Plasticidad y Restauración Neurológica, 3*(1 y 2), 45-57.

Aguilar Tamayo, M. F. (2004b). *El Mapa Conceptual: Un texto a interpretar*. Artículo presentado en First International Conference on Concept Mapping. CMC2004, Pamplona, España.

Aguilar Tamayo, M. F. (2005). *Representaciones visuales-conceptuales del conocimiento y estructura del hipermedia educativo.* Tesis no Publicada Type, Universidad Autónoma del Estado de Morelos, Cuernavaca, México.

Aguilar Tamayo, M. F. (2006). *Origen y destino del mapa conceptual. Apuntes para una teoría del mapa conceptual.* Artículo presentado en Second International Conference on Concept Mapping (CMC2006. 5-8 de Septiembre), San José, Costa Rica.

Aguilar Tamayo, M. F. ((en prensa)). El mapa conceptual, una representación visual del concepto científico desde la perspectiva de Vygotski. En: Univerisidad Autónoma del Estado de Morelos.

Ausubel, D. P. (2002). *Adquisición y retención del conocimiento. Una perspectiva cognitiva*. España: Paidós.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cole, M. (2000). *Cultural Psychology. A once and future discipline*. Cambridge: Harvard University Press.

Daniels, H. (2003). *Vygotsky y la pedagogía*. México: Paidós.

John-Steiner, V., & Mahn, H. (1996). Sociocultural Approaches to Learning and Development: A Vygotskian Framework. *Educational Psychologist*(31), 191-205.

Kozulin, A. (2000). *Instrumentos psicológicos. La educación desde una perspectiva sociocultural*. España: Paidós.

Novak, J. D. (1982). *Teoría y práctica de la educación*. España: Alianza.

Novak, J. D. (1998). *Conocimiento y aprendizaje. Los mapas conceptuales como herramientas facilitadoras para escuelas y empresas*. Madrid: Alianza.

Novak, J. D. (2002). Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappopriate Propositional Hierarchies Leading to Empowerment of Learners. *Science Education, 4*(86), 548-571.

Novak, J. D. (2004). *A Science Education Research Program that led to the Development of the Concept Mapping Tool and New Model for Education.* Artículo presentado en Firts International Conference on Concept Mapping, Pamplona, España.

Novak, J. D., & Cañas, A. J. (2004). *Building on New Constructivist Ideas and CMapTools to Create a New Model for Education.* Artículo presentado en First International Conference on Concept Mapping, Pamplona, España.

Novak, J. D., & Gowin, B. (1988). *Aprendiendo a aprender*. Barcelona: Martínez Roca.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28*(1), 117-153.

Pozo, J. I. (1994). *Teorías cognitivas del aprendizaje* (3ra. ed.). España: Morata.

Pozo, J. I. (2003). *Adquisición de conocimiento*. España: Morata.

Rivière, Á. (2002). *La psicología de Vygotski* (5ta. ed.). España: Visor.

Vygotski, L. S. (1979). *El desarrollo de los procesos psicológicos superiores*. Barcelona: Crítica.

Vygotski, L. S. (1995). Historia del desarrollo de las funciones psíquicas superiores. En: L. S. Vygotski (Ed.), *Obras escogidas III* (Vol. III, pp. 11-340). España: Aprendizaje Visor.

Vygotski, L. S. (1997). El método instrumental en psicología. En: *Obras Escogidas I* (Vol. I, pp. 65-70). España: Aprendizaje Visor.

Vygotski, L. S. (2001). Pensamiento y Lenguaje. En: *Obras Escogidas II* (pp. 10-348). España: Antonio Machado Libros.

Vygotsky, L. (1995). *Pensamiento y Lenguaje*. España: Paidós.

Wertsch, J. V. (1985). *Vygotsky and the Social Formation of Mind*. Cambridge: Harvard University Press.

Wertsch, J. V. (1993). *Voces de la mente. Un enfoque sociocultural para el estudio de la Acción Mediada*. España: Visor.

Wertsch, J. V. (1998). *Mind as Action*. USA: Oxford University Press.

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EL MAPA CONCEPTUAL(MC): UN INSTRUMENTO IDÓNEO PARA FACILITAR LA COMPRENSIÓN LECTORA

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Abstract. Se muestran en el presente trabajo algunos ejercicios prácticos de comprensión lectora, realizados por alumnos/as pertenecientes a 6º curso de Educación Primaria(12 años), utilizando la estrategia de los mapas conceptuales(MMCC). Constituyen excelentes ejemplos que muestran la eficacia de los MMCC para paliar uno de los más acusados problemas de la educación actual, que es el de la deficiente comprensión de los textos expositivos, que existe en la mayoría de los alumnos. La construcción de MMCC requiere la implicación total del alumno, lo que redunda en un trabajo mental intenso y muy interesante de cara a la comprensión lectora, que no es sino un aspecto del aprendizaje significativo(AS). Basándose en la idea de que la comprensión de un texto es una actividad que implica procesos de acceso a la memoría semántica, asimilación de ideas nuevas a las dadas y definición de puntos de anclaje entre unas y otras, se establece un paralelismo entre este proceso de pensamiento y el de construcción de MMCC.

1 Introducción

Nuestro trabajo propone el empleo de los mapas conceptuales (en adelante MMCC) como herramienta/instrumento idóneo para trabajar la comprensión de textos expositivos.

Diversas evaluaciones llevadas a cabo en distintos momentos de la educación Primaria (alumnos de 6 – 12 años), tanto a nivel regional, nacional e incluso internacional, han puesto de manifiesto que la comprensión lectora es uno de los aspectos educativos en los que los alumnos españoles obtienen peores resultados. A estas mismas conclusiones llega John T. Bruer (1995) cuando afirma que "muy pocos niños adquieren habilidades de comprensión de alto nivel. Son capaces de descodificar, pero no pueden comprender ni utilizar lo que descodifican –no pueden construir la esencia-. Nos tenemos que centrar en cómo enseñar esas habilidades lectoras de alto nivel".

A partir del último informe PISA (curso 2003-04), el Gobierno de la Comunidad Foral de Navarra (España) se ha propuesto priorizar el trabajo en este campo (mejora de la comprensión lectora de los alumnos de enseñanza Primaria) y ha elaborado un plan bianual: Plan ATLANTE, a desarrollar durante los cursos 2005-06 y 2006-07 en todos los centros educativos de la Comunidad. En dicho plan se persigue la consecución de seis objetivos, el primero de los cuales es: "Mejorar la comprensión lectora de libros de texto u otros materiales utilizados por el profesorado para el aprendizaje en todas las áreas del currículo". En su desarrollo se da prioridad a los textos narrativos y expositivos.

Como ya ha quedado dicho al principio y así lo expusimos en un trabajo reciente (Iraizoz y González, 2003), consideramos que el trabajo con MMCC puede contribuir en gran medida y de forma eficaz a la consecución de tal objetivo.

Desde un primer momento queremos dejar claro nuestro convencimiento de que la lectura comprensiva no puede ser considerada como un hecho aislado al margen del proceso de aprendizaje. Las teorías personales sobre el funcionamiento del mundo que vamos elaborando a partir de los conocimientos que adquirimos en nuestra vida diaria, servirán para dar significado a todo lo que acontece a nuestro alrededor y funcionan como puntos de anclaje para los nuevos aprendizajes. Todo esto va a constituir los conocimientos previos, pieza clave en el proceso de comprensión lectora.

No tiene sentido hablar de lectura sin comprensión, "leer no es la simple recitación de significantes, sino la revelación de significados. Entender un texto es revelar su significado o, al menos, el esfuerzo por conseguir esa revelación. La lectura errónea es la que crea un discurso que no corresponde al significado"(Morón, 1966).

Comprender un texto supone darle significado y equivale esencialmente al hecho de pensar. La psicología cognitiva considera a la lectura como un proceso de pensamiento, de solución de problemas en el que están involucrados conocimientos previos, hipótesis, anticipaciones y estrategias para interpretar ideas implícitas y

explícitas (Puente, 1996**).** Todo el inmenso depósito de conocimientos estructurados (lingüísticos y saberes, esquemas y creencia sobre el mundo) que almacenamos en la memoria permanente va a ser fundamental en el proceso de comprensión. Cuando leemos nos enfrentamos al texto selectivamente tratando de responder a una serie de preguntas específicas que nos vamos formulando en función de esos esquemas contenidos en nuestra estructura mental y que oportunamente activamos. Tendremos la sensación de haberlo comprendido cuando sintamos el estado de incertidumbre cero, es decir, de que no nos queda ninguna pregunta sin responder. Los buenos lectores, incluso, se saben hacer preguntas como: ¿está funcionando mi estrategia de comprensión?, ¿cómo lo estoy haciendo?, ¿tiene sentido la esencia que he identificado?, etc.; es decir, supervisan el propio proceso de comprensión aplicando habilidades metacognitivas a la lectura. La construcción de un mapa conceptual (MC en adelante) refuerza la aplicación de estas habilidades metacognitivas, ya que a cada paso llevan al alumno a replantearse los conocimientos que posee cuando se ve en la necesidad de tener que establecer las relaciones que se dan entre los conceptos y sobre todo cuando debe especificar las relaciones (enlaces) existentes entre ellos.

Al hablar de comprensión lectora nos ponemos en el punto de vista de la mente del lector más que en el de la estructura del escrito, ya que es el propio lector quien aporta el significado al material impreso. Así Emerson (cit. por Puente, 1996) afirma que "los libros los hacen los grandes lectores", la lectura la realiza esencialmente el cerebro humano contando para ello más con la información no visual que con la visual.

En un sentido muy general, la comprensión del discurso es una actividad que implica esencialmente procesos de acceso a la memoria semántica y recuperación de la información previamente poseída, asimilación de ideas nuevas a las dadas y definición de puntos de anclaje entre unas y otras. De nuevo, se nos ocurre hacer un paralelismo entre el proceso de pensamiento y el de construcción de un MC puesto que en los mapas unos conceptos sirven de anclaje para otros.

Si la comprensión de cualquier texto es un objetivo fundamental en el proceso educativo, la de los textos expositivos tiene, si cabe, más relevancia, ya que es la forma en la que habitualmente se presentan los textos escolares y según Black (cit. por Mayor y Pinillos, 1992) "son los que propiamente transmiten información nueva sobre la realidad y explican nuevos temas". Estos textos describen relaciones lógicas entre acontecimientos y objetos en orden a informar, explicar o persuadir (Brewer, cit. por Mayor y Pinillos, 1992). A diferencia de los textos narrativos, mucho más simples de estructura y muy entroncados con la experiencia vital de los alumnos, los textos expositivos plantean cierta dificultad y obligan al lector a aplicar todos los recursos cognitivos disponibles, convirtiendo su lectura en una tarea compleja.

Los procesos psicológicos que intervienen en el texto expositivo están dirigidos a extraer las relaciones entre los elementos descritos en el contenido del texto, formando una representación de la estructura lógica del mismo. Los procesos transforman la configuración estimular (el texto que se exhibe ante nuestros ojos) en una representación semántica. Esta transformación supone, básicamente, una *abstracción* mediante la que se selecciona y se sintetiza la información, una *elaboración*, en la que entran en juego los conocimientos previos del sujeto que lee y, la adopción de una forma *representación organizada* con la que el contenido del texto es almacenado en la memoria.

La revisión de abundante bibliografía sobre el proceso de la comprensión lectora nos reafirma en el convencimiento de la idoneidad de los MMCC como instrumentos para su facilitación y mejora. En primer lugar está el consejo de los lingüistas de utilizar la escritura como la mejor forma de leer. La escritura, cuando se realiza conscientemente, constituye el modo más operativo de comprensión. En este sentido proponemos el MC como una forma consciente de escritura. Los escritores hábiles poseen esquemas de escritura: fórmulas generales o guiones, que son los que al leer emplea para resolver los problemas que se le van planteando en lo que supone el hecho de comprender. Applesee, (cit. por Bruer, 1984) afirma, al respecto, que "aunque las investigaciones sobre escritura todavía no han probado que una mejora en las habilidades de escritura comporta una mejora en las habilidades de aprendizaje y razonamiento, algún día se descubrirá que en realidad es así". La escritura no sólo sirve para mostrar lo que se ha aprendido, sino que también contribuye a expresar lo que uno piensa sobre lo que ha aprendido, es decir, es una buena estrategia para transformar la mera información que un texto lineal transmite en conocimiento útil, susceptible de ser enseñado. Lo que Meichenbaum y Biemiller (1998) denominan dominio del conocimiento. Al convertir a nuestros alumnos en hábiles constructores de MC les estaremos dotando de una herramienta con la que desentrañar el contenido de cualquier texto que se les presente.

Un segundo argumento lo constituyen las seis funciones que Palincsar y Brown (cit. por Bruer, 1984) descubrieron y consideraron esenciales para la comprensión lectora:

- El lector competente *entiende* que el objetivo de la lectura es construir significado.
- Al leer, *activa* sus conocimientos de base relevantes.
- *Centra* la atención o los recursos cognitivos en las principales ideas del contenido.
- *Evalúa* el significado construido en función de su conciencia interna, su compatibilidad con los conocimientos previos y el sentido común.
- *Extrae* y *prueba* las inferencias que va estableciendo.
- Y *supervisa* todo lo anterior para ver si se da la comprensión.

Todas ellas son puestas en juego en el proceso de construcción de un MC, bien espontáneamente por parte del alumno a lo largo del mismo, o, de forma dirigida, en la negociación que podrá llevarse a cabo, entre profesor y alumno, o entre alumnos, a la vista de los resultados que se vayan obteniendo.

El tercero lo encontramos en la forma en que, según hemos dicho anteriormente, los procesos psicológicos intervienen en la comprensión de un texto expositivo, en cómo se dirigen a extraer las relaciones que se dan entre elementos del texto con el objeto de formar una representación de su estructura lógica. El MC puede considerarse una representación gráfica de tal estructura, Novak (1982) ve en ellos una especie de fotografía de la forma en que el alumno tiene organizada la información en su memoria semántica, o cuando menos, de la forma que adquiere o tiene para él en el contexto en el que se construye el mapa. El MC que el alumno elabora en base al texto propuesto, servirá al profesor para conocer lo que el alumno ha comprendido y negociar con él, en el caso de que no se corresponda con el contenido real del texto.

Así mismo, tal y como más adelante se expondrá, acertamos a ver un paralelismo entre el proceso de construcción del MC y los procesos de abstracción, elaboración y creación de la estructura jerarquizada que contribuyen a crear la representación semántica del texto.

La definición que Belinchón, Riviere e Igoa (1992) dan de la comprensión de un texto: "supone la creación de un texto base que organiza jerárquicamente todas las ideas explícitas en el texto de superficie", de nuevo nos hace pensar en un MC.

Dentro de los dos grupos de teorías que existen a propósito de las representaciones mentales de los textos: las basadas en la estructura del texto (Meyer) y las basadas en los esquemas (Kintsch y Van Dijk, 1978), nosotros nos posicionamos a favor de las últimas. Estos últimos autores, al igual que Just y Carpenter (1980), afirman que comprender un texto: "es construir una representación cognitiva de los contenidos del mismo a través de la acción de diversos procesos". Según Kintsch y Van Dijk, la representación mental del texto (su compresión) se realiza en función de los procesos utilizados para analizarlo y especifican que ésta ocurre en tres niveles de procesamiento. Cada uno de ellos da lugarr a una representación específica: microproposiciones, macroproposiciones (resultantes de la agrupación de microproposiciones) y macroestructura (resultado de la síntesis de las macroproposiciones)

Kintsch (cit. por Belinchón, Rivière e Igoa, 1992) propone el **texto base** como elemento para analizar los fenómenos de comprensión y memoria de un texto. Este texto base, compuesto de ideas (conceptos y proposiciones) es elaborado por el lector tomando como punto de partida el **texto de superficie**, es decir, el formado por las palabras y oraciones contenidas en el documento que se lee. Pero, el texto base trasciende al de superficie ya que va más allá de la suma de las ideas moleculares (proposiciones) que conforman este último.

El texto base se representa mediante un conjunto de proposiciones ordenadas en diferentes niveles jerárquicos. En él se establece un primer nivel de estructura, denominado por Kintsch y Van Dijk (obra citada), **microestructura,** la cual constituye el requisito necesario para dotar al texto de coherencia y que, además, determina el nivel jerárquico de las proposiciones. Un segundo nivel es el denominado **macroestructura**, o estructura de conocimiento. Para que surja este segundo nivel es necesario que, además de la microestructura, intervenga el complejo y organizado conjunto de conocimientos que lector debe poseer referidos tanto al contenido del texto como a la organización del mismo. En este nivel confluyen por tanto procesos que van de abajo a arriba, y de arriba abajo. Los conocimientos previos desempeñan en el proceso de comprensión lectora un papel fundamental ya que son responsables de distintas funciones; por un lado, permiten la integración y elaboración de los textos, por

otro, facilitan el que se lleven a cabo las inferencias y predicciones que permiten el proceso lector, y por último, dirigen la selección y control de la información adecuada.

Como ya hemos apuntado anteriormente, consideramos que es posible establecer un paralelismo entre estos niveles de procesamiento y los pasos seguidos para la construcción de un MC. En un primer momento y guiados por los conocimientos previos, realizaremos la selección de los conceptos y proposiciones sencillas (microproposiciones) contenidas en el texto objeto de lectura, al mismo tiempo que empezamos a esbozar el aspecto general del mapa, determinando cuál es el concepto más inclusor y cómo los demás conceptos se disponen en los sucesivos niveles jerárquicos hasta llegar a los más concretos. Este primer trabajo puede identificarse con ese primer proceso de abstracción que hemos mencionado más arriba, a medio camino entre la micro y la macroestructura. Tras esta primera ordenación jerárquica y primera explicitación de los enlaces, vendría una revisión más profunda que llevaría a una ordenación definitiva y a una mayor matización de las relaciones. Estaríamos ya en la fase de elaboración. En ella los conocimientos previos juegan un papel fundamental. Además de aportar la información que se requiere, van a ser objeto de una continua evaluación aportando las respuestas a las sucesivas preguntas que el lector se hace y que, como ya se ha mencionado antes, constituyen lo que genuinamente se entiende como comprensión. Estas respuestas estarán constituidas por las proposiciones que se han elaborado, así como por la forma en que el MC se organiza. La estructura definitiva se establecerá cuando el lector incluya en su MC enlaces cruzados, los cuales hacen explícitas relaciones originales –propias del lector- que basadas en un cuerpo de conocimientos previos bien organizados, nos permitirán evaluar la capacidad creativa de los alumnos.

2 Descripción, resultados y discusión de la experiencia

Proponemos en este apartado varios ejemplos de cómo alumnos pertenecientes a sexto curso de Primaria han empleado los MMCC como instrumento para trabajar la comprensión lectora.

Los MMCC que se presentan y comentan a continuación constituyen una `pequeña muestra de los muchos que a lo largo de nuestra dilatada experiencia profesional han elaborado nuestros alumnos en distintos momentos del proceso de aprendizaje. Los hemos utilizado como herramientas para evaluar –al comienzo y final de la instrucción-, como medio fundamental para hacer posible el aprendizaje significativo, como recurso para facilitar la comprensión de un texto..., siendo realizados, tanto individual como colectivamente.

Todos ellos han sido elaborados por alumnos correspondientes a sexto curso de Primaria (12 años), con amplia experiencia en la construcción de MMCC, y con el objetivo de que interpretaran textos referidos al área de Conocimiento del Medio (ciencias naturales y sociales).

Los dos primeros mapas se elaboraron a partir del siguiente texto:

CLIMA

El clima es el conjunto de características de los elementos atmosféricos (temperaturas, precipitaciones, vientos...) que predominan en una determinada zona de la Tierra. El clima de un lugares está determinado por varios factores. Los más importantes son: la latitud, la proximidad o lejanía al mar, la altitud y la disposición del relieve. La latitud es la distancia de un punto de la Tierra al Ecuador. La temperatura desciende a medida que aumenta la latitud. En las zonas próximas al mar las temperaturas son más frescas en verano y más cálidas en invierno que en las tierras situadas en el interior. Además, cerca del mar hay más humedad, lo que favorece las precipitaciones. Con la altitud la temperatura disminuye y aumentan las precipitaciones. La disposición del relieve también modifica las temperaturas y las precipitaciones, ya que las montañas aíslan las tierras interiores de la influencia del mar.

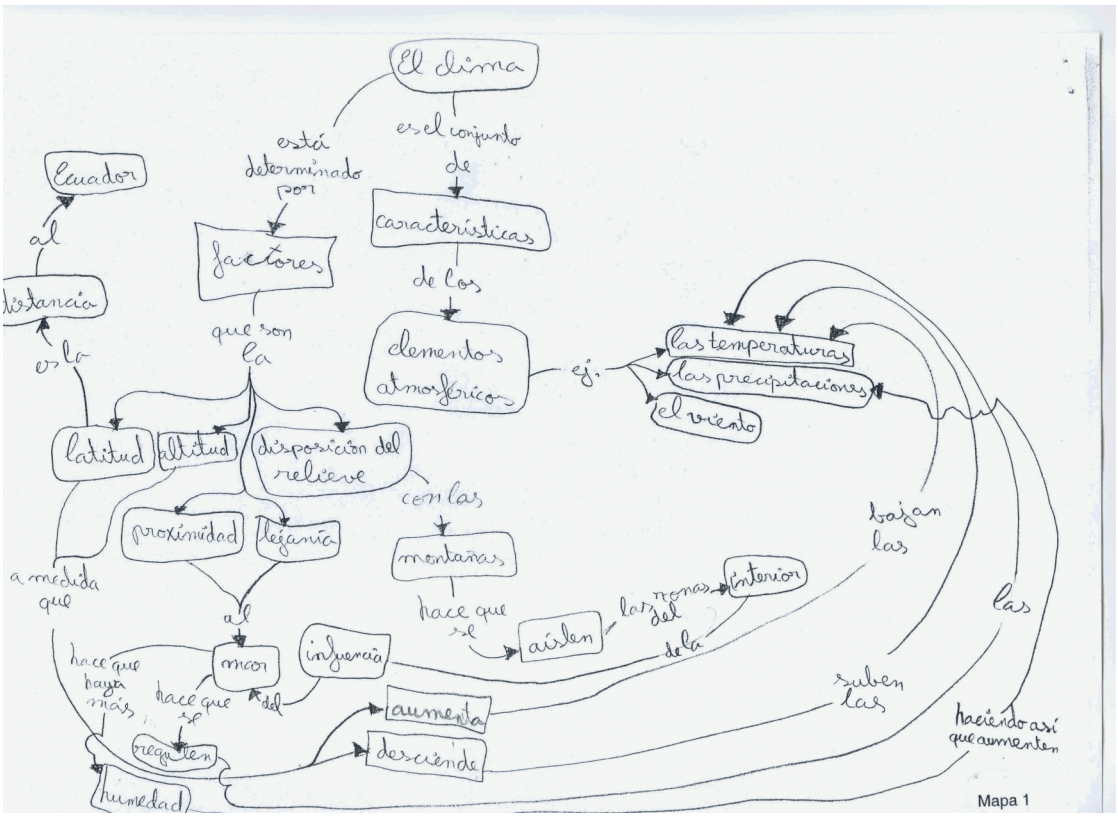


Figura 1: Mapa 1

La alumna autora del mapa, tras la lectura inicial del texto subrayó en él los conceptos que consideró interesantes y, posteriormente, elaboró la siguiente relación:

clima
características
elementos atmosféricos: temperaturas
precipitaciones
vientos
factores: latitud
altitud
disposición del relieve
mar (cercanía, lejanía)
distancia
Ecuador
descender (no es un concepto)
aumentar (no es un concepto)
verano
invierno
interior
humedad
aislar (no es un concepto)
influencia

En ella podemos ver cómo identifica elementos atmosféricos y factores como dos ideas importantes a las que subordinar otras. Esta diferenciación no siempre resulta fácil para los alumnos de esta edad. Nos parece que bien podría haber prescindido de la definición de clima ya que no es sino una transcripción literal del texto.

Ha leído la información a la luz de los conocimientos previos que posee, ha realizado una buena abstracción y en la relación propuesta puede adivinarse ya cuál va a ser la estructura general del MC que construirá.

Su lectura nos confirma esa buena comprensión. Las dos secuencias, inicialmente separadas y que en algunos casos resultan excesivamente largas y reiterativas, se ponen en relación mediante enlaces cruzados que sirven para explicar las relaciones de causa-efecto existente entre factores y elementos atmosféricos.

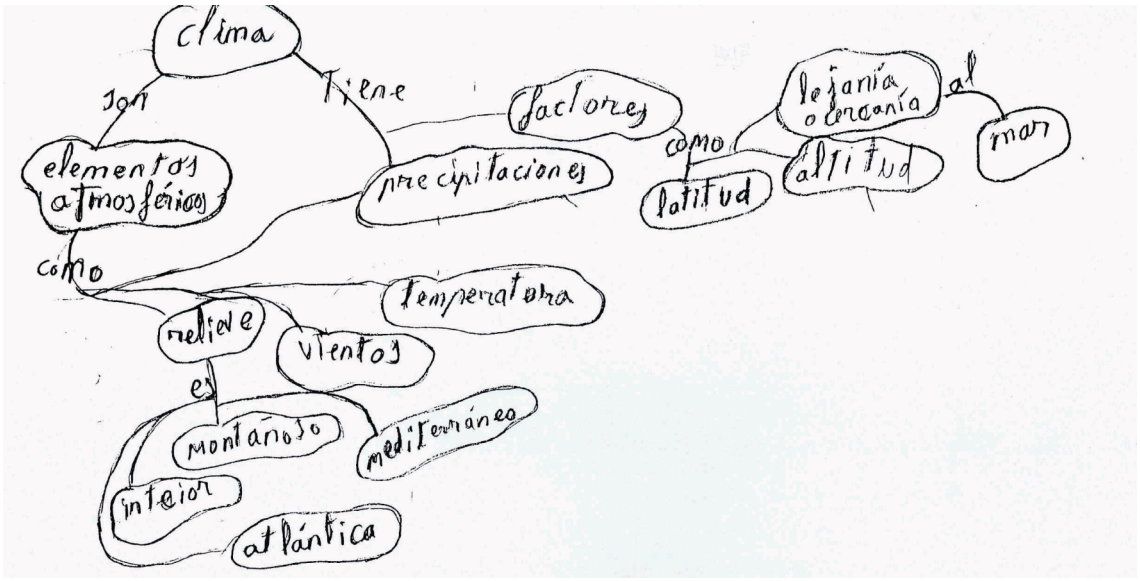


Figura 2: Mapa 2

Este segundo mapa ha sido construido por un alumno perteneciente a la misma clase y que por tanto ha participado en el mismo proceso de instrucción. En este caso, aunque también se establecen dos secuencias lineales a partir del concepto clima, la separación inicial entre ellas no es acertada. Conceptos que deben subordinarse bien al concepto elementos atmosféricos, bien a factores, aparecen anclados erróneamente. A esto hay que añadir que los enlaces son, en la mayoría de los casos simples líneas que nada explican. En este caso, vemos que el alumno falla en un primer paso que supondría la transcripción, casi literal del contenido del texto; al que seguiría las que deberían ser aportaciones hechas desde sus conocimientos previos y que quedarían reflejadas en los términos de enlace. A todo esto, añadiríamos la falta de enlaces cruzados explicando las relaciones causa-efecto entre ambas secuencias lineales las cuales constituyen la información fundamental del texto y que el alumno no ha sido capaz de captar.

Los dos mapas que a continuación se exponen corresponden a otras dos alumnas del mismo curso, en este caso elaborados a partir del siguiente texto:

ÁTOMO

Todas las cosas están formadas por unas partes pequeñísimas de materia llamadas átomos. Los átomos son tan minúsculos que no pueden verse ni aún con la ayuda de los microscopios. Un sabio de la Antigüedad, el griego Demócrito, creía que esas partes de la materia debían ser sólidas, y por ello las llamó átomos. En griego, átomo significa algo que no se puede dividir. Pero últimamente, los científicos han descubierto que, en realidad, el átomo está formado por partes todavía más pequeñas. En el centro del átomo se halla el núcleo, formado por unas partículas llamadas neutrones y protones. Alrededor del núcleo giran un tercer tipo de partículas, llamadas electrones.

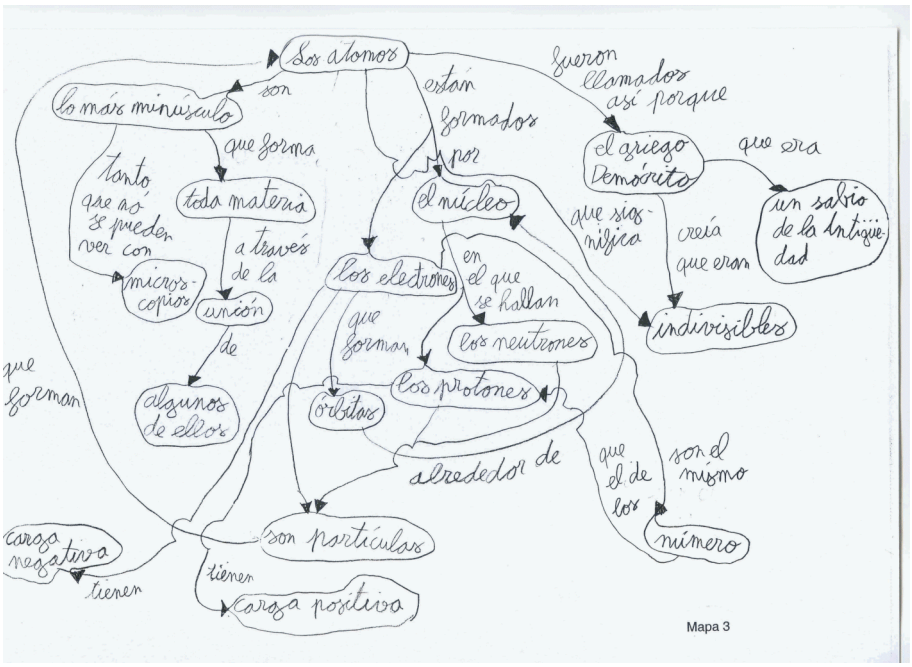


Figura 3: Mapa 3

Este primer mapa, al que le podríamos reprochar la presencia de secuencias lineales excesivamente largas, pone de manifiesto un conocimiento bien estructurado, por tanto una buena comprensión del contenido del texto. Incluye más información que la contenida en la lectura, procedente, sin duda, de los conocimientos previos existente en la memoria semántica de la alumna. La gran abundancia de enlaces cruzados es una manifestación del alto valor que la alumna concede al hecho de aprender. Esto, además, contribuye a crear una estructura mental cada vez más sólida, base para futuros y más amplios conocimientos.

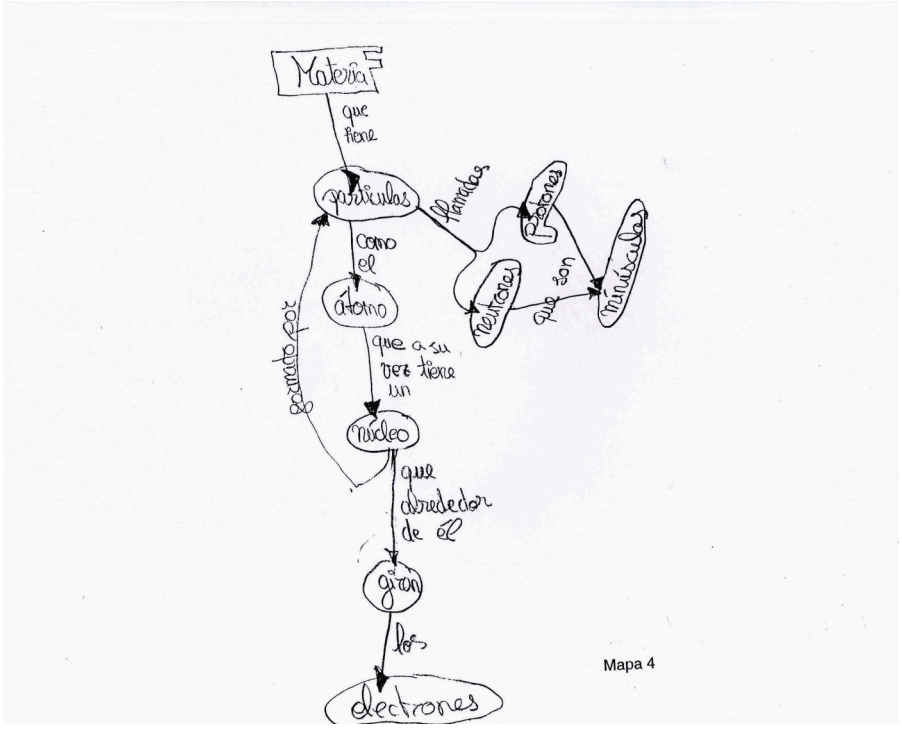


Figura 4: Mapa 4

Este segundo mapa contrasta ampliamente con el anterior. Sorprende, en primer lugar el hecho de no haber elegido como concepto más inclusor a *átomo*. Tal vez esto constituya ya una primera evidencia de que la alumna no sabe extraer el tema o idea principal de la lectura. Subordina átomo a partículas, dándole a éstas una relevancia que no le corresponde en el texto y a la que ancla la reducida información que extrae del discurso. Los conceptos, además de resultar escasos, los va encadenando linealmente con explicaciones vagas que no forman verdaderas proposiciones.

Si consideramos el mapa como un reflejo gráfico de la estructura mental que el lector construye a partir del texto, pone de manifiesto una mala comprensión y podrá ser utilizado como punto de partida para negociar significados que a la larga conduzcan a mejorar la comprensión lectora

3 Conclusiones

Nuestra experiencia de muchos años en la utilización del MC como herramienta de aprendizaje en el aula y, de la que los ejemplos expuestos no son sino una pequeña muestra, nos permite invitar a utilizarlos por las siguientes razones:

- La construcción del mapa es un acto consciente de escritura, actividad que es considerada por los lingüistas como la mejor estrategia de comprensión lectora.
- Supone una exigencia de participación activa del lector, la cual no es fácil de conseguir en el aula con otros procedimientos. El trabajo con mapas, sobre todo empleando el programa de CmapTools (Cañas et al., 2004), motiva y consigue implicar a los alumnos de forma intensa, lo que sin duda beneficia el proceso de comprensión lectora y en general el aprendizaje.
- Esta forma de escritura requiere, además, un proceso de construcción en el que es posible identificar aquellos pasos que parece seguir un lector cuando se enfrenta a la comprensión de un texto. Con ello le estamos entrenando, y por tanto, dotando de una estrategia que podrá utilizar cuando se enfrente a la comprensión de un texto
- El resultado del proceso de construcción del mapa es una materialización que puede ser evaluada a la vez que compartida y negociada. Ello le va a permitir al profesor conocer lo que el alumno ha comprendido, así como negociar con él conocimientos insuficientes o, incluso, erróneos.

Por todo lo expuesto y a modo de conclusión aconsejamos el empleo de los MMCC como herramienta para la mejora de la comprensión de textos expositivos y en general como instrumento adecuado para aprender significativamente.

4 Referencias bibliográficas

Belinchón, M., Riviere, A., Igoa, M.A. (1992). *Psicología del Lenguaje. Investigación y Teoría*. Madrid: Ed. Trotta.

Bruer, J. T. (1995). *Escuelas para pensar. Una ciencia del aprendizaje en el aula*. Barcelona: Ediciones Paidós.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Iraizoz Sanzol, N. y González García, F. M. (2003). *El mapa conceptual: un instrumento apropiado para comprender textos expositivos*. Pamplona: Gobierno de Navarra, Departamento de Educación.

Mayor, J. y Pinillos, J. L. (1992). *Memoria y representación.* Madrid: Alhambra Logman.

Meichenbaum, D. y Biemiller, A. (1998). *Nurturing Independent Learners. Helping Students Take Charge of their Learning*. Cambridge Mass.: Brookline Books.

Morón, C.(1966). La lectura ideal y el ideal de la lectura, en Cerrillo, P. y García Padrino, J.(coords.), *Hábitos lectores y animación a la lectura*. Cuenca: Ediciones de la Universidad Castilla-La Mancha.

Novak, J.D. (1982). *Teoría y práctica de la educación.* Madrid: Alianza Editorial S.A.

Puente, A. (1996**).** Cómo formar buenos lectores, en Cerrillo, P. y García Padrino, J.(coords.), *Hábitos lectores y animación a la lectura*. Cuenca: Ediciones de la Universidad Castilla-La Mancha.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

EL USO DE MAPAS CONCEPTUALES PARA PROMOVER EL APRENDIZAJE SIGNIFICATIVO DEL TEMA PREVENCIÓN DE ADICCIONES CON ADOLESCENTES MEXICANOS DE NIVEL SECUNDARIA

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Resumen.. En esta investigación se utilizaron los mapas conceptuales para comprobar si favorecían el aprendizaje significativo de conceptos relacionados con el tema de adicciones en adolescentes mexicanos que cursaban el primer grado de secundaria. Los mapas conceptuales tuvieron tres funciones: como *estrategia de aprendizaje* (los alumnos aprendieron la técnica y generaban un mapa personal), como *estrategia de enseñanza* (el docente los empleaba para explicar los conceptos del tema) y como *estrategia de evaluación* (para explorar el nivel de comprensión de los conceptos del tema y detectar los errores conceptuales). Se trabajó con 96 estudiantes con edades entre 12 y 14 años, 57% mujeres y 43% hombres, distribuidos en tres grupos. Las condiciones de experimentación fueron: el grupo 1 no recibió entrenamiento en mapas conceptuales; el grupo 2 recibió entrenamiento en mapas conceptuales como estrategia de aprendizaje; y el grupo 3 recibió entrenamiento en mapas conceptuales como estrategia de aprendizaje y la enseñanza fue a su vez apoyada por mapas como estrategia instruccional. El análisis estadístico de los datos indica que los mapas conceptuales contribuyeron a la construcción significativa del conocimiento, sucediendo que el grupo donde se emplearon los mapas conceptuales en la doble modalidad de estrategia de aprendizaje y enseñanza resultó el más favorecido, seguido del grupo donde se emplearon sólo como estrategia de aprendizaje; estos dos grupos superaron considerablemente al grupo que no recibió entrenamiento. Comparando el pretest y el postest, se encuentra que los alumnos de los grupos 2 y 3 incrementaron las puntuaciones obtenidas en los mapas, lo que demuestra tanto un mayor dominio de la técnica como de la calidad de la representación del conocimiento. Se propone que se puede extender el empleo de los mapas conceptuales a la enseñanza de contenidos procedimentales, como serían el proceso de toma de decisiones y prevención de adicciones en el adolescente.

1 Introducción

Los mapas conceptuales han representado un invaluable instrumento educativo para favorecer la comprensión de conceptos. Diversas investigaciones han puesto de manifiesto su utilidad, aunque hay que reconocer que el corpus de conocimiento, al menos en el nivel de educación secundaria, se concentra en temas relacionados con el aprendizaje de conceptos científicos y se ha investigado menos lo relativo a conceptos sociales, psicológicos, cívicos o éticos. No obstante, tal como quedó manifiesto en el I Congreso Internacional sobre Mapas Conceptuales que se celebró en Pamplona, España en el 2004, se está incursionando en otros campos disciplinares y en otras aplicaciones de dicha estrategia cognitiva.

Por este motivo, la presente investigación trabajó con mapas conceptuales en un ámbito poco explorado: el tema de *prevención de adicciones* de la asignatura Educación Cívica y Ética, la cual forma parte del currículo oficial de la educación secundaria mexicana. Los mapas conceptuales se diseñaron y emplearon siguiendo los principios descritos por Novak y Gowin (1998), es decir, como una estrategia cognitiva efectiva para ayudar a estudiantes y educadores a captar el significado de los materiales que se van a aprender, como un recurso para representar el conjunto de significados conceptuales incluidos en una estructura de proposiciones, y como un resumen esquemático de lo que se ha aprendido cuando se ha completado una tarea de aprendizaje. Así, los mapas conceptuales constituyeron en nuestro caso una representación explícita y manifiesta de los conceptos y proposiciones que posee un alumno o profesor según el caso, y fungieron como una estrategia de enseñanza, aprendizaje o evaluación, dependiendo de los fines y la manera en que fueron utilizados.

En diversas investigaciones se ha mostrado que los mapas conceptuales ayudan al aprendiz a hacer más evidentes los conceptos clave o las proposiciones que se van a aprender a la vez que le permiten identificar conexiones entre diversos conceptos. En particular, permiten vincular el conocimiento previo con los nuevos contenidos de aprendizaje potenciando así el aprendizaje significativo (Díaz Barriga y Hernández, 2002). Asimismo, los mapas conceptuales promueven el llamado aprendizaje visual, ya que son un medio idóneo para visualizar conceptos y relaciones jerárquicas entre conceptos. Su empleo como estrategias de aprendizaje y evaluación efectivas también ha sido demostrado (Gouveia y Valadares, 2004). Sin embargo, en algunos estudios se demuestra que para que los mapas conceptuales sean efectivos en la promoción del aprendizaje significativo es necesario que los alumnos reciban un entrenamiento apropiado en el uso de esta estrategia, donde se les ofrezca supervisión y

realimentación a sus producciones, tengan la posibilidad de comparar sus propios mapas con mapas de referencia (mapas de expertos) o bien discutan y elaboren los mapas con sus pares en ambientes colaborativos (Álvarez y Arias, 1998; Contreras, 1997; Fonseca, 2000). Es decir, sólo los estudiantes bien entrenados en la comprensión y manejo de la estrategia se benefician de la misma, y más aún si se fomentan tareas colaborativas donde se produce la compartición y construcción conjunta de significados. Por otra parte, algunas investigaciones ponen de manifiesto la utilidad de los mapas conceptuales en la identificación a nivel diagnóstico de las preconcepciones de los alumnos o incluso de los errores en la enseñanza (Arellano y Lazo, 2003; Valadez y Téllez, 2000).

2 Pregunta y objetivos de la investigación

La pregunta de investigación planteada fue: ¿Resultará efectivo el uso de mapas conceptuales para favorecer la adquisición significativa de conceptos relacionados al tema de adicciones de la materia de Formación Cívica y Ética en alumnos de primer grado de secundaria? Por su parte, los objetivos del estudio fueron: a) Determinar si a través de los mapas conceptuales se favorece la adquisición significativa de conceptos relacionados con el tema de prevención de adicciones en función de su uso como estrategia de aprendizaje, enseñanza y evaluación; b) Diseñar una propuesta para entrenar a los alumnos en el empleo de mapas conceptuales así como para enseñar el tema referido a través de dicha estrategia y; c) Contrastar si la enseñanza de mapas conceptuales es más efectiva en función del tipo de entrenamiento recibido, del uso que se hace de los mismos y del tipo de enseñanza que ofrece el agente educativo frente al grupo.

3 Contexto educativo y participantes

La investigación se realizó en una escuela secundaria pública de la Ciudad de México ubicada en una zona de nivel socioeconómico bajo, tipificada como zona de alto riesgo debido a la alta incidencia entre la población juvenil de diversos tipos de adicciones así como de actos de violencia y pandillerismo. Se trabajó con tres grupos de primer grado del turno vespertino; fueron 96 estudiantes con edades entre 12 y 14 años, 57% mujeres y 43% hombres, distribuidos en tres grupos, cada uno con 32 sujetos. Los grupos se asignaron al azar a las condiciones de experimentación siguientes: el grupo 1 no recibió entrenamiento en mapas conceptuales; el grupo 2 recibió entrenamiento en mapas conceptuales como estrategia de aprendizaje; y el grupo 3 recibió entrenamiento en mapas conceptuales como estrategia de aprendizaje y la enseñanza fue a su vez apoyada por mapas como estrategia instruccional. El diseño de la investigación fue cuasiexperimental con tres grupos intactos evaluados mediante pretest-postest.

4 Procedimiento

El desarrollo de la investigación se llevó a cabo en cuatro fases designadas de la siguiente manera:

I. Fase de Diagnóstico: Se aplicó a los alumnos un cuestionario de conocimientos (pretest) con preguntas de opción múltiple y abiertas para valorar qué tanto conocían de los conceptos clave del tema y se exploró asímismo si manejaban la elaboración de mapas conceptuales.

II. Fase se Entrenamiento: Se entrenó a dos de los tres grupos a elaborar mapas conceptuales; en esta fase se les proporcionó un manual elaborado por las experimentadoras tomando como referente a Novak y Gowin (ob. cit.) y a Ontoria, Molina y De Luque (1996). En el entrenamiento y manual respectivo se incluyeron:

Actividades de Preparación

- Reconocimiento de términos conceptuales.
- Reconocimiento de imágenes mentales y de términos conceptuales.
- Reconocimiento de palabras de enlace.
- Reconocimiento de nombres propios.
- Construcción de proposiciones.

Aplicación de conocimientos

- Se trabajó con un texto de entrenamiento: lectura en silencio, identificación de términos conceptuales importantes y de palabras de enlace.

Actividades de construcción del mapa conceptual que se trabajó anteriormente.

- Lista de conceptos
- Lista de palabras de enlace
- Construcción del mapa conceptual
- Se dieron indicaciones de datos técnicos
- Cada alumno realizó su mapa conceptual
- Se comparó el mapa conceptual de los participantes con un mapa maestro elaborado por las investigadoras
- Se hizo un segundo mapa conceptual

III. Fase de Enseñanza:

Conforme al programa de la asignatura, el tema de prevención de adicciones abarca los siguientes conceptos clave: *adicción, tipos y causas de las adicciones, consecuencias personales y sociales de las mismas, drogas de uso legal e ilegal, conductas asertivas ante las adicciones*. Se plantea que es importante partir de hechos reales y que el alumno comprenda la importancia de la no dependencia de sustancias adictivas y de fijar límites personales.

Como antes se indicó, el grupo 1 no recibió entrenamiento en mapas conceptuales, mientras que el grupo 2 sí recibió entrenamiento; la profesora a cargo de la asignatura impartió la clase empleando las estrategias didácticas habituales que consideraba pertinentes (principalmente empleó exposición, así como toma de apuntes, resolución de cuestionarios, uso de esquemas o lectura del libro de texto). En el grupo 3 (con entrenamiento en mapas conceptuales), las experimentadoras impartieron la clase sobre el tema de adicciones haciendo uso de los mapas conceptuales. Los alumnos realizaron hasta 10 mapas, cada uno centrados en los conceptos clave del tema; previo a la elaboración del mapa se realizaba la lectura en voz alta y discusión correspondiente al contenido con base en el libro de texto de Formación Cívica y Ética I. Después de elaborar los mapas, los alumnos los presentaban y discutían en grupo y los comparaban con el mapa de referencia elaborado por las investigadoras. Éstas hacían las aclaraciones pertinentes al manejo de la estrategia y del tema según fuera requerido. Cabe resaltar nuevamente que las condiciones de tratamiento permitieron explorar el empleo de mapas conceptuales en su calidad de estrategias de aprendizaje y/o enseñanza y que debido a la secuencia de mapas elaborados por los alumnos durante el entrenamiento (grupos 2 y 3), también fue posible ver su potencial como estrategia de evaluación del aprendizaje.

IV. Fase de Evaluación: Una vez concluida la impartición del tema en los tres grupos, se les aplicó nuevamente el cuestionario de conocimientos (postest) para ver si había o no diferencias después del tratamiento. También se les proporcionaron diferentes textos relacionados al tema de adicciones con el objetivo de que eligieran uno y elaboraran un mapa conceptual a partir de éste.

5 Resultados

En esta sección se presentarán los resultados más importantes obtenidos tanto en la prueba de conocimientos como en el análisis de los mapas conceptuales elaborados por los alumnos de los tres grupos en el pretest y postest respectivos.

5.1 Conocimientos sobre el tema de adicciones

En relación con la prueba de conocimientos del tema de adicciones, en la Tabla 1 se presentan los estadísticos descriptivos obtenidos en el prestest y postest con los tres grupos.

	Grupo	N	Media	Desviación estándar	Error estándar	95% Intervalo de confianza de la media		Mínimo	Máximo
						Límite inferior	Límite superior		
PRETEST Conocimientos del tema	**1**	32	13.734	4.4901	.7937	12.116	15.353	7.0	28.0
	2	32	16.531	4.5454	.8035	14.892	18.170	9.0	28.0
	3	32	17.906	5.3467	.9452	15.979	19.834	5.0	28.0
	Total	96	16.057	5.0689	.5173	15.030	17.084	5.0	28.0
POSTEST Conocimientos del tema	**1**	32	16.719	4.8226	.8525	14.980	18.457	9.0	30.0
	2	32	20.453	3.9663	.7012	19.023	21.883	14.0	29.0
	3	32	31.188	7.2287	1.2779	28.581	33.794	11.0	44.0
	Total	96	22.786	8.2330	.8403	21.118	24.455	9.0	44.0

Tabla 1. Estadísticos descriptivos de la prueba de conocimientos Pretest-Postest

Considerando las puntuaciones obtenidas por cada uno de los grupos en el pretest se observan varias cuestiones: una considerable variabilidad entre los alumnos pero en general un desempeño más bien bajo que pone de manifiesto su conocimiento deficiente del tema de adicciones y las diferencias de desempeño entre grupos que suelen aparecer cuando se trabaja con grupos intactos, es decir, grupos naturales que ya están formados antes de la investigación. En el postest, después de haberse sometido a las diferentes condiciones de tratamiento, se observa un incremento en las puntuaciones de los tres grupos y en ese sentido puede afirmarse que hubo un progreso favorable en la adquisición de conceptos relacionados al tema. No obstante, al observar las medias que obtuvieron los grupos ($X = 16.719$ para el grupo 1, $X = 20.453$ para el grupo 2 y $X = 31.188$ para el grupo 3) se encuentra que los mayores incrementos los logró el grupo 3, seguido del grupo 2 y finalmente el grupo 1.

Con los datos anteriores se aplicó un análisis de varianza unidireccional entre los grupos considerando los tipos de intervención y los momentos de evaluación para identificar si existían diferencias estadísticamente significativas. Tal como se aprecia en la Tabla 2, los resultados muestran que con una probabilidad de .003 se presenta una diferencia significativa en los resultados obtenidos en el prestest y con una probabilidad de .000 se observa una diferencia altamente significativa en los resultados obtenidos en el postest. Los grupos mostraron ser heterogéneos antes de ser sometidos a las condiciones de intervención ($F=6.251$); no obstante, después del entrenamiento en mapas conceptuales, las diferencias de desempeño entre los grupos se acentuaron significativamente en función del tipo de tratamiento recibido ($F=59.361$).

Fuente de Variación		Suma de Cuadrados	df	Medias cuadráticas	Razón F	Significancia de F
PRETEST C.	**Entre Grupos**	289.255	2	144.628	6.251	.003
	Intragrupos	2151.680	93	23.136		
	Total	2440.935	95			
POSTEST C.	**Entre Grupos**	3610.849	2	1805.424	59.361	.000
	Intragrupos	2828.523	93	30.414		
	Total	6439.372	95			

Tabla 2. Análisis de Varianza Unidireccional (ANOVA)

Para corroborar la dirección de los cambios encontrados, con los datos anteriores se realizaron una serie de comparaciones múltiples entre las condiciones de tratamiento, considerando la comparación por pares de los tres grupos tanto en el pretest como en el postest. Los resultados fueron los siguientes:

5.2 Pretest

- Grupo 1 – Grupo 2, presenta un nivel de significancia de .072, no hay diferencias significativas.
- Grupo 1 – Grupo 3, presenta un nivel de significancia de .003, sí hay diferencias significativas.
- Grupo 2 – Grupo 3, presenta un nivel de significancia de .522, no hay diferencias significativas.

5.3 Postest

- Grupo 1 – Grupo 2, presenta un nivel de significancia de .029, sí hay diferencias significativa.
- Grupo 1 – Grupo 3, presenta un nivel de significancia de .000, sí hay diferencias significativas.
- Grupo 2 – Grupo 3, presenta un nivel de signiicancia de .000, sí hay diferencias significativas.

En conjunto, los resultados anteriores permiten aceptar la hipótesis de investigación, esto es, el uso de mapas conceptuales en la enseñanza del tema de adicciones de la materia de Formación Cívica y Ética 1 favorece la adquisición significativa de conceptos relacionados a este tema. Indican asimismo que en el pretest había diferencias en el nivel de conocimientos del grupo 3 y el 1, pero no entre los demás. Por otro lado en el postest las diferencias apuntan a favor del entrenamiento en mapas conceptuales, resultando más efectiva la modalidad de entrenamiento combinado en estrategia de enseñanza y aprendizaje (grupo 3), seguida de entrenamiento como estrategia de aprendizaje (grupo 2) y al final con el desempeño más pobre, el grupo que no recibió entrenamiento en mapas conceptuales, que apenas avanzó cerca de tres puntos del pretest al postest (grupo 1).

6 Evaluación de los mapas conceptuales elaborados por los alumnos

La evaluación de los mapas conceptuales se realizó con base en los criterios de puntuación establecidos por Novak y Gowin (ob. cit.). Las puntuaciones obtenidas en los mapas conceptuales por los alumnos en el pretest, fueron muy bajas, ya que como se observa en la Tabla 3, más del 90% de los alumnos de cada grupo no pudieron realizar un mapa conceptual apropiado; la mayoría elaboró algún tipo de esquema o red de conceptos o contenidos temáticos que no incluía un desglose válido de proposiciones ni reflejaba vínculos ni jerarquías apropiadas. Se puede afirmar que en el momento de aplicar el pretest, la inmensa mayoría de los alumnos de los tres grupos no sabía elaborar un mapa conceptual. Lo anterior puede parecer sorprendente, puesto que el mapa conceptual es un recurso didáctico que aparece con frecuencia en los libros de texto de secundaria y los alumnos sí estaban familiarizados con el vocablo, no así con la elaboración apropiada de dicha estrategia.

Categorías y puntuación	Grupo 1	Grupo2	Grupo 3
No hizo mapa conceptual o hizo otro tipo de representación gráfica. Calificación 0 puntos	29 (90.6%)	30 (93.7%)	31 (96.8%)
Mapas a nivel incipiente. Calificación de 1 a 7	0 (0%)	1 (3.1%)	0 (0%)
Mapas de desarrollo intermedio. Calificación de 8 a 15 puntos	2 (6.25%)	1 (3.1%)	1 (3.1%)
Mapas Conceptuales avanzados. Calificación de 16 a 20 puntos	1 (3.1%)	0 (0%)	0 (0%)

Tabla 3. Niveles de puntuación de los mapas conceptuales realizados en el Pretest (Frecuencias y porcentajes por grupo)

Después de la intervención y con base en la evaluación de los mapas elaborados en el postest, podemos ver que las puntuaciones obtenidas por los grupos 2 y 3 aumentaron considerablemente, sobre todo en éste último, mientras que en el grupo 1 no hubo cambios significativos, tal como se puede apreciar el la Tabla 4. Los datos más sobresalientes son:

- El 93.75% de los alumnos del grupo 1 (sin entrenamiento, ni clase a través de mapas conceptuales) se mantuvo en la primer categoría (no supieron elaborar un mapa conceptual), en tanto que sólo el 6.5% se ubicó en la categoría de mapas de desarrollo intermedio.
- El 62.5% de los alumnos del grupo 2 (con entrenamiento en mapas conceptuales) obtuvo puntuaciones que se ubican en su mayoría en la categoría de mapas de desarrollo intermedio; el restante 37.5% se ubicó en la primer categoría, mapas incipientes.
- Casi la totalidad de los alumnos del grupo 3 (con entrenamiento en mapas conceptuales y enseñanza del tema de adicciones a través de éstos) aprendieron a elaborar mapas conceptuales apropiados que se ubicaron en mapas de desarrollo intermedio. Dos alumnos elaboraron mapas avanzados y uno se ubicó en la categoría de mapa incipiente.

Cabe mencionar que las categorías se conformaron tomando como referente la puntuacón más baja y la más alta obtenida por los alumnos (0 y 36 puntos respectivamente). Con base en éstas se conformaron 3 rangos o niveles que variaban en 12 puntos, quedando conformados el nivel incipiente (1-12 puntos), intermedio (13-24 puntos) y el avanzado (25-36 puntos); para aquellas representaciones que se puntuaron con cero, se conformó la categoría de "no mapa", es decir, cuando el alumno no había elaborado propiamente un mapa conceptual.

Categorías y puntuación	**Grupo 1**	**Grupo2**	**Grupo 3**
No hizo mapa conceptual o hizo otro tipo de representación gráfica. Calificación 0 puntos	30 (93.75%)	12 (37.5%)	0 (0%)
Mapas a nivel incipiente. Calificación de 1 a 12 puntos	0 (0%)	4 (12.5%)	1 (3.12%)
Mapas de desarrollo intermedio. Calificación de 13 a 24 puntos	2 (6.25%)	13 (40.62%)	29 (90.6%)
Mapas Conceptuales avanzados. Calificación de 25 a 36 puntos	0 (0%)	3 (9.37%)	2 (6.25%)

Tabla 4. Niveles de puntuación de los mapas conceptuales realizados en el Postest. Frecuencias y porcentajes por grupo

Aún cuando no fue un propósito planteado en el estudio, la revisión cualitativa de los mapas elaborados por los alumnos permitió a las experimentadoras identificar algunas concepciones erróneas en los alumnos. En particular, destacó por su frecuencia la idea de que una adicción sólo puede darse cuando se trata de sustancias o drogas ilegales y la asociación del concepto adicción con el de "vicio", dejando fuera otro tipo de adicciones (a la comida, la televisión, el sexo, el trabajo, etc.). También apareció con frecuencia la idea de que para dejar una adicción, todo lo que tiene que hacer la persona es desear hacerlo (voluntarismo) o bien disminuir el consumo ("que no lo haga tanto"). También resultó evidente que a los alumnos lo que se les dificultaba más sobre el tema era proponer medidas para la prevención y la atención de las conductas adictivas tomando en cuenta su complejidad y la multideterminación de factores y agentes en juego. Esta información, obtenida desde el pretest, permitió a las investigadoras trabajar explícitamente tales ideas con los estudiantes del grupo 3, lo que también explica el avance que éstos mostraron en el postest en comparación a los otros dos grupos. Para ilustrar el tipo de mapas elaborados por los participantes en esta investigación, se ofrece un mapa conceptual (Figura 1) con los contenidos que incluyó una alumna del grupo 3, el cual se calificó como mapa avanzado.

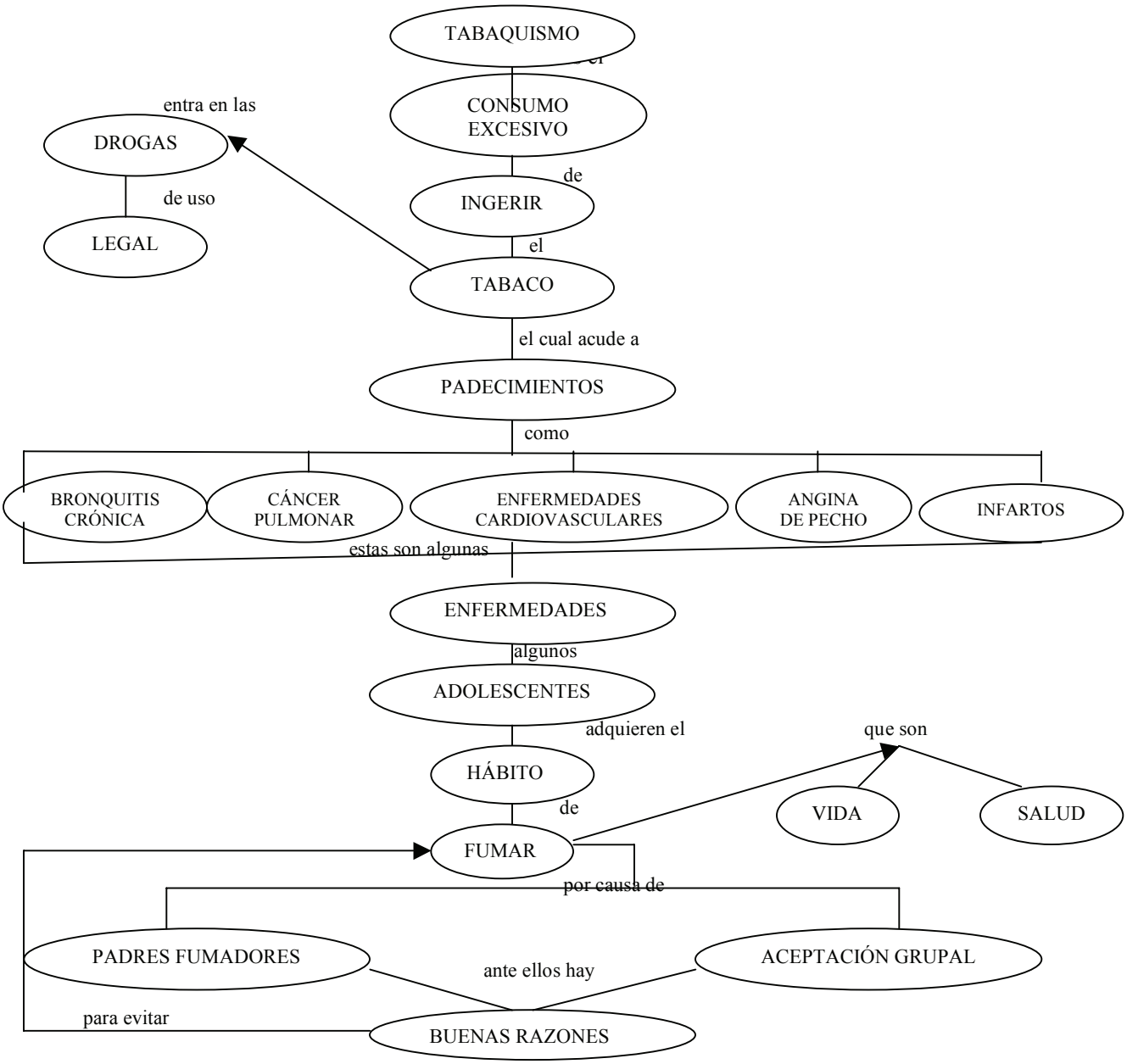


Figura 1. Mapa conceptual avanzado elaborado por una alumna del grupo 3.

7 Conclusiones y perspectivas de la investigación

Se concluye que el uso de mapas conceptuales en la enseñanza del tema de prevención adicciones favoreció la adquisición significativa de los conceptos clave relacionados al mismo. La propuesta de entrenamiento y el manual diseñado para enseñar a los alumnos a elaborar mapas conceptuales resultó ser efectiva tomando en cuenta los resultados de los dos grupos entrenados. Se corroboró que el empleo de los mapas conceptuales resultó ser más efectivo cuando se reunían ciertas condiciones: un entrenamiento apropiado e informado y su uso combinado como estrategia de aprendizaje e instruccional, dando oportunidad a los alumnos de evaluar colaborativamente sus mapas y contrastarlos con el mapa del experto. Por otra parte, los mapas apoyaron la planeación de la secuencia didáctica de parte de las experimentadoras y les permitieron detectar las principales concepciones erróneas y confusiones en que incurrían los alumnos. Finalmente, en los mapas elaborados no sólo se plasmaba el contenido propiamente

conceptual del tema, sino también llegaba a aparecer la valoración ética o actitud del alumno respecto a las adicciones y la comprensión eventual que habían logrado de cómo hacer frente a ellas. Por esto último proponemos, como perspectivas de investigación futura, el estudio y empleo de los mapas conceptuales o variantes de esta estrategia en la enseñanza de los componentes actitudinal-valorativo y procedimental de temas como el aquí abordado o afines, incursionando de forma similar a Beirute y Mayorga (2004) en la enseñanza de estrategias para la toma de decisiones, prevención y solución de problemas.

8 Agradecimiento

Quiero manifestar mi profundo reconocimiento a la maestra que me ha enseñado a "aprender a aprender", quien me apoyó durante todo el camino de esta investigación y siempre hizo observaciones fundamentales para que este sueño se volviera realidad, gracias maestra Frida por sus enseñanzas que me han ayudado a crecer profesionalmente, con el cariño que usted se ha sabido ganar, le dedico este trabajo en el cual tuve la oportunidad de aprender a través su experiencia: Minerva.

9 Referencias

Arellano, M. y Lazo, L. (2003). La evaluación diagnóstica, los mapas conceptuales y la UVE de Gowin como estrategia para evaluar la actividad experimental. *Memorias de XVII Jornadas de Evaluación en la Educación Superior* de la Pontificia Universidad Católica del Valparaíso, Chile.

Álvarez, E. y Arias, H. (1998). El aprendizaje de algunos conceptos fundamentales en el campo de la botánica. Una experiencia investigación aula. *Revista de la Facultad de Ciencia y Tecnología*, (4), 69-73, Universidad Pedagógica Nacional, Colombia.

Beirute, L, Mayorga, L. (2004). Los mapas conceptuales herramienta poderosa en la resolución alternativa de conflictos. En: A. Cañas, J. Novak y F. González, (Eds.). *Concept maps: Theory, Methodology and Technology. Proceedings on the First International Conference on Concept Mapping*. Pamplona, España: Dirección de Publicaciones de la Universidad Pública de Navarra, volumen 2, pp. 65- 69.

Contreras, L. (1997). El uso de mapas conceptuales como herramienta educativa en el ámbito de los números racionales. *Enseñanza de las Ciencias*, 15 (1), 111-122.

Díaz Barriga, F. y Hernández, G. (2002). *Estrategias docentes para un aprendizaje significativo*. México: McGraw Hill.

Fonseca, O. (2000). Hipertextos y Mapas Conceptuales en Ambientes de Aprendizaje Colaborativo. *Revista de la Facultad de Ciencia y Tecnología*. Universidad Pedagógica Nacional 8, 38-55.

Gouveia, V, y Valadares, J. (2004). Concept maps and the didactic role of assessment. En: A. Cañas, J. Novak y F. González, (Eds.). *Concept maps: Theory, Methodology and Technology. Proceedings on the First International Conference on Concept Mapping*. Pamplona, España: Dirección de Publicaciones de la Universidad Pública de Navarra, volumen 1, p.p. 303-309

Novak, J., y Gowin, D. (1988). *Aprendiendo a aprender*. Barcelona: Martínez Roca.

Ontoria, A., Molina, A. y De Luque, A. (1996). *Los mapas conceptuales en el aula*. Argentina: Magisterio del Río de la Plata.

Valadez, R. y Téllez, M. (2000). Errores en la enseñanza de la evolución del hombre. *Correo del Maestro*: *Revista para Profesores de Educación Básica*, 4, (48), 37-45, mayo.

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ENHANCING CONCEPT MAPPING TOOLS BELOW AND ABOVE TO FACILITATE THE USE OF SUPERIMPOSED INFORMATION

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Abstract. In this paper, we describe ways of enhancing concept mapping tools to facilitate representation and use of *superimposed information*. Superimposed information refers to new interpretation of existing information and involves working with information at various document granularities (sub-document, complete document, and multi-document). We illustrate our approach by showing how enhanced concept mapping tools may be used with two superimposed applications: SIMPEL and Strand Maps.

1 Introduction

Concept maps are used to represent an individual/group's understanding of something (e.g., an idea, a domain of knowledge, a topic). In many applications, like teaching and research, concept maps can be considered to be new interpretations of existing information. For example, when a student is trying to write a paper, she could annotate information resources, and organize various annotations and references into a concept map that may represent the outline of the paper that she is trying to write. She also may attach relevant resources (including multimedia content) to concepts to provide more detailed information or to remind her of the works associated with various concepts. Thus, in some sense, she is *superimposing* new information (the concept map and annotations) over existing information (references used).

In research and other scholarly activities, we rarely treat all parts of a document (information resource) in a uniform manner. When building concept maps, a concept (or group of concepts) often refers to a part of a document. Although current concept mapping tools like IHMC CmapTools (Cañas, A. J., Hill, G. et al. 2004) and GetSmart (Marshall, B., Zhang, Y. et al. 2003) allow users to build concept maps and attach multimedia resources, they are limited in their ability to reference information at sub-document granularity. We believe that such a capability can be useful in many applications.

In this paper, we present an approach to enhance concept mapping tools using the idea of *superimposed information*. We demonstrate our approach by enhancing the IHMC CmapTools in two ways: *below* – by providing a mechanism to reference information at sub-document granularity, and *above* – by introducing some additional modeling and knowledge management constructs and tools that can help represent superimposed information. We illustrate these enhancements using two example superimposed applications.

2 Superimposed Information

Superimposed information (SI) refers to new interpretation of existing information (Maier, D. and Delcambre, L. 1999). This could be in the form of new content – like annotations, comments, etc. – or new structures – like tables of contents, concordances, back of the book indexes (an example of hierarchical list structures), or concept maps (graph structures). Superimposed applications (SAs) allow users to overlay new interpretations over existing or *base information*, typically to highlight, annotate, elaborate, select, collect, organize, connect, or reuse information elements. SAs employ "marks", which are references to selected regions within base information (of text or multimedia content) that also may carry media-specific summaries (e.g., text abstracts, image thumbnails).

SAs may make use of the Superimposed Pluggable Architecture for Contexts and Excerpts (SPARCE), middleware that provides mark management and other services (Murthy, S., Maier, D. et al. 2004). Information in marks includes document format information (e.g., HTML, PDF, media file formats like .WMV), an address for the containing document, and a specification of the location of the selected region within that document. It also includes mark creation properties like mark creator, as well as timestamp and

machine-specific information. Marks may be used to obtain the excerpt (content) and the context (properties like font size, whether the selected region is a hyperlink, etc.) of the selected region. Marks can be referred to, manipulated as first class objects, and resolved (bringing back the "base level" document with the marks highlighted in a way suitable for the particular type of media involved).

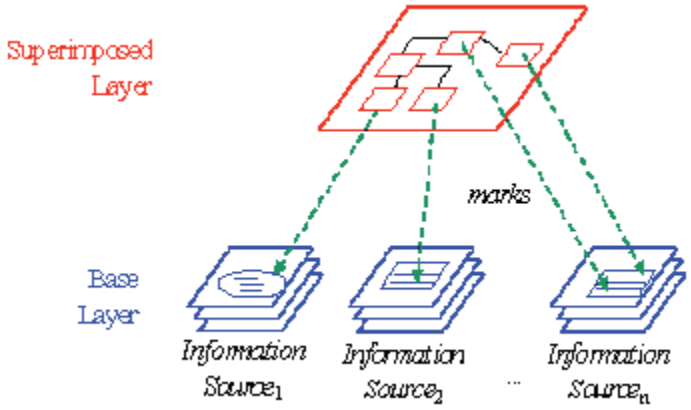


Figure 0. (Source: (Murthy, S. and Maier, D. 2003)) Layers of information and marks in an SI system.

Figure 1 shows the different layers of information and marks in an SI system. Information (documents) in the superimposed layer usually follow a structure (e.g., schema) specified by the SA, sometimes referred to as the superimposed structure. SAs enable us to (a) deal with information at varying granularity (sub-document, complete document, and multi-document), and (b) select or work with information elements at sub-document level while retaining the original context (by referencing information, not replicating).

3 Enhancing IHMC CmapTools to Provide Support for SI

Concept maps represent a type of superimposed information. Current concept mapping tools like IHMC CmapTools (Cañas, A. J., Hill, G. et al. 2004) and GetSmart (Marshall, B., Zhang, Y. et al. 2003) have certain features that allow them to be used as a superimposed application. For example, they allow:

- Representation of SI using concepts and links
- Connecting concepts and links (superimposed information) to resources (base information) at complete document and multi-document levels (attaching one or more resources to a concept/link)

However, these tools are limited in their capability to reference/link information at the sub-document level. In addition, they still need a method to represent superimposed structure, or the structure of an SI document.

We believe that by enhancing concept mapping tools *below* and *above*, we can provide these capabilities to better support an SI system. By enhancing *below*, we mean providing capability to connect concepts and linking phrases to information at sub-document granularity. One way to achieve this is by treating marks as resources. By enhancing *above*, we mean enabling concept mapping tools with capabilities to represent richer semantics and structure, and make them more expressive, in order to represent superimposed structures. We believe that this may be accomplished by allowing concepts and linking phrase constructs to represent additional structures that go beyond the proposition structure (concept-linking phrase-concept).

We are working towards providing SI support in IHMC CmapTools. Currently, we have taken advantage of the URI representation of a mark (explained in (Murthy, S. 2005)) and use it as a web address resource in CmapTools. As shown in Figure 2, this enables connecting of concepts and links to information at the sub-document level. In Figure 2, the concept “hypertext” is connected to a mark (describing the concept) within an HTML document.

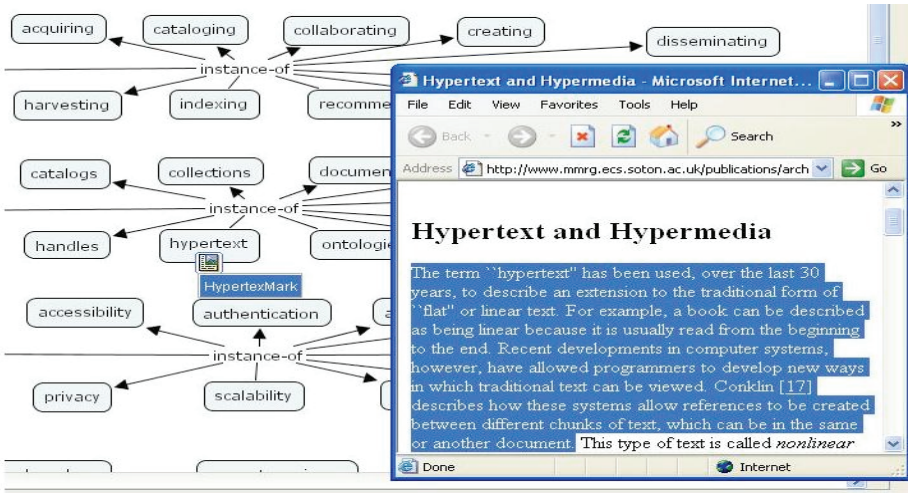


Figure 2. A section of a concept map on "Taxonomy of Digital Library Terms". The concept "hypertext" has a mark attached that points to a section describing hypertext in an HTML document (shown highlighted in blue).

To demonstrate how concept mapping tools may be enhanced *above*, we show how CmapTools may be used with two superimposed applications – SIMPEL and Strand Maps. Note: these enhancements are to a concept mapping tool, namely, the IHMC CmapTools, and not necessarily to the concept map model.

3.1 SIMPEL

```
<presentation>
  <name>Memex.xml</name>
   <location>D:\SIMPEL</location>
   <begin_time>
     <value>1</value>
     <item>
       <id>2005_12_1_16_14_53_718_MemexAudio</id>
       <name>MemexAudio</name>
       <mark_id>WMPMediaMark2005Dec01161413EDUCATIOQY40U5KapilAhuja</mark_id>
       <span_time>43</span_time>
       <channel_id>PaneA</channel_id>
     </item>
   </begin_time>
   <begin_time>
     <value>2</value>
     <item>
       <id>2005_12_1_17_13_24_15_BushText</id>
       <name>BushText</name>
       <mark_id>HTMLMark2005Dec01171301EDUCATIOQY40U5KapilAhuja</mark_id>
       <span_time>10</span_time>
       <channel_id>PaneC</channel_id>
     </item>
   </begin_time>
 </presentation>
```

Figure 3. A section of the XML representation of a SIMPEL presentation describing Vannevar Bush's Memex

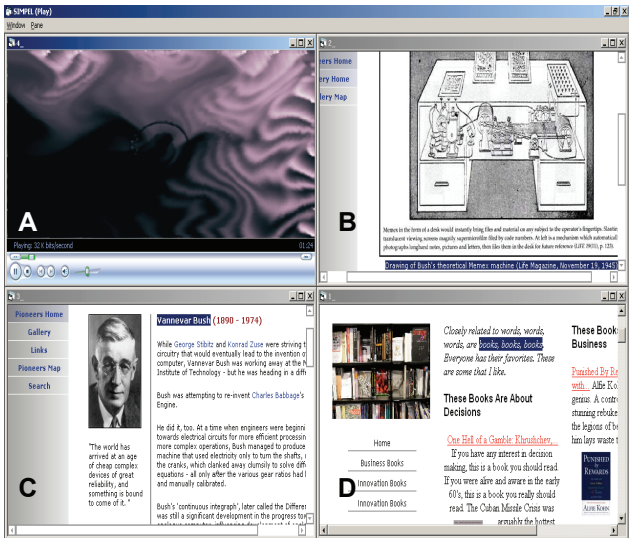


Figure 4. The SIMPEL "play" interface, showing a presentation describing Vannevar Bush's Memex. Pane A contains an audio clip. Panes B, C, and D show selected information within web pages.

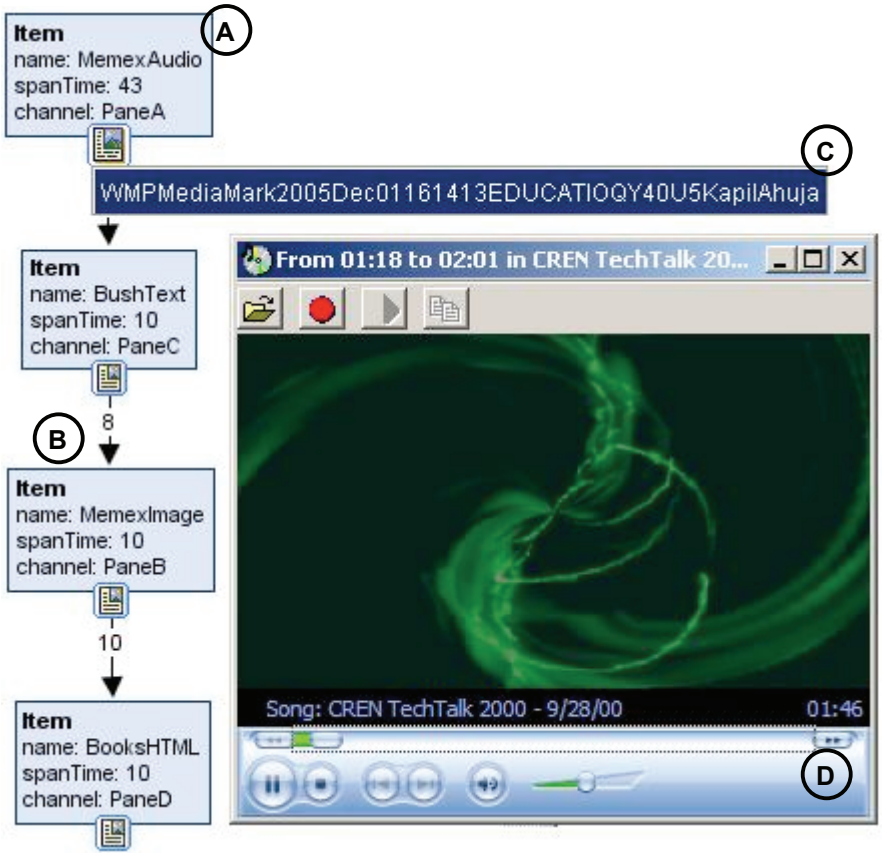


Figure 5. A CmapTools concept map representation of a SIMPEL presentation. A) Concepts represent items and are each associated with at least one mark; B) Ordering of items is represented by directed links. The linking phrases represent the relative time difference (in seconds) between the playing of two items; C) The highlighted mark points to an audio clip describing Vannevar Bush's memex; D) The audio clip playing in a media player (the complete audio file is a talk on digital libraries).

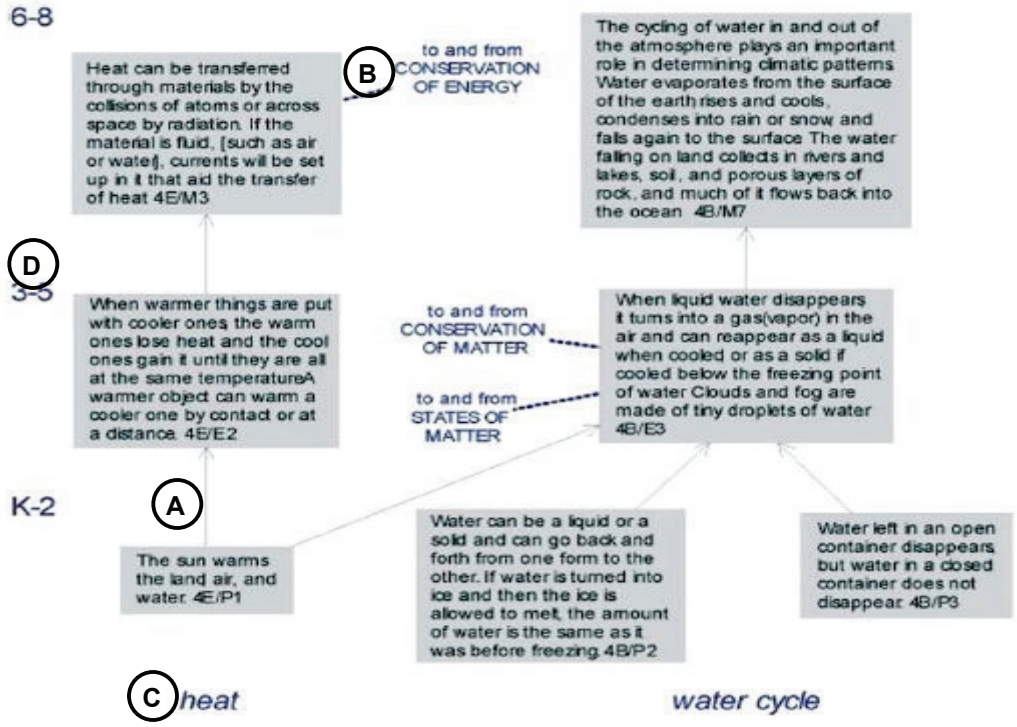


Figure 6. (Source: (Sumner, T., Ahmad, F. et al. 2005)) A section of a strand map called "*Weather and Climate*" – the full map consists of 22 benchmarks, 7 of which are shown here. A) The arrows indicate how one benchmark supports the ideas in the next benchmark. B) Dotted lines show connections to other maps (e.g., *Conservation of Energy*). C) Vertical strands are shown in the bottom of the map (e.g., heat and water cycle). D) Grade-levels are shown on the left (e.g., K-2, 3-5, etc)

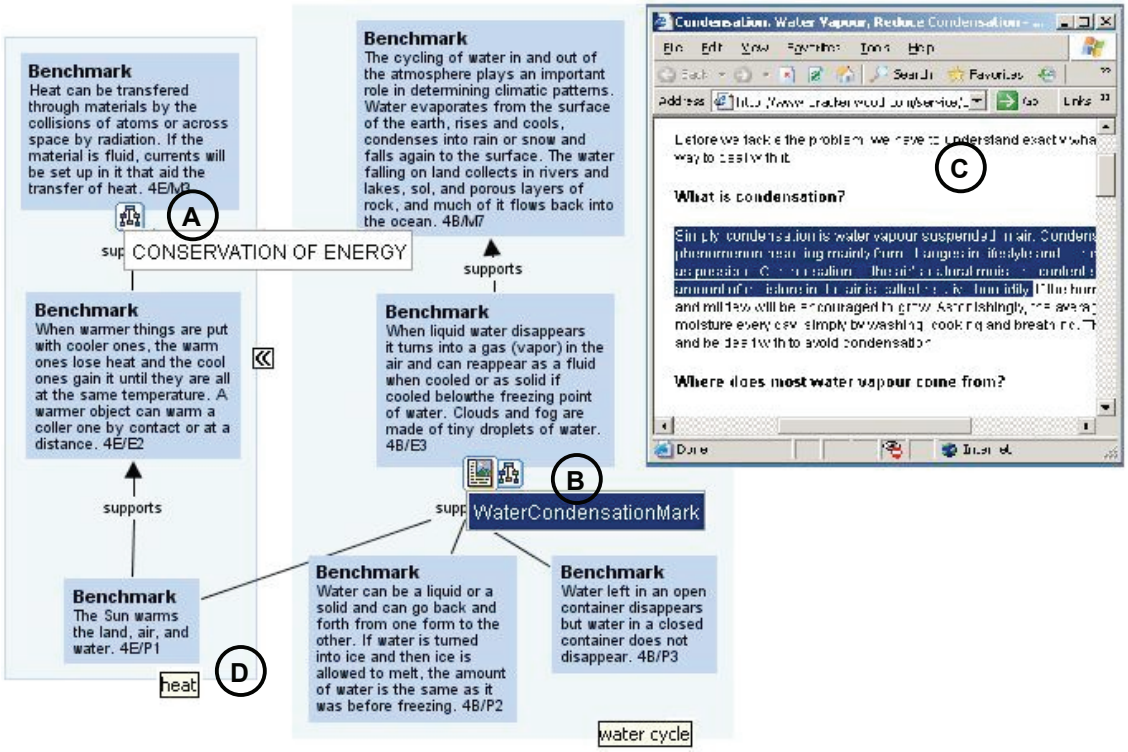


Figure 7. A CmapTools concept map representation of the "Weather and Climate" strand map shown in Figure 5. Benchmarks are represented by concepts, and links represent relationships between benchmarks. A) Connection to other strand maps; B) A condensation mark, attached as a resource to a benchmark; C) Activation of the condensation mark shows the selected information in its original context; D) Nested nodes and matching tooltips signify vertical strands in a strand map.

The Superimposed Multimedia Presentation Editor and Player (SIMPEL), is an SA that allows a user to reference information of many types (including text and multimedia content), at varying levels of granularity, and compose synchronized multimedia presentations from this information (Murthy, U., Ahuja, K. et al. 2006). For example, for a specific topic a user can select an audio clip, some images, and some text. She then can "play" (i.e., render in specific panes of a window) this information-set in some order. Figure 3 shows the XML representation of a SIMPEL presentation, describing Vannevar Bush's memex. Figure 4 shows a snapshot of SIMPEL's play interface, playing the same presentation.

In Figure 5, we show one way of using a CmapTools concept map to represent a SIMPEL presentation (emphasizing the structure of the superimposed document). The figure is a result of merging multiple snapshots of various actions on the concept map. A SIMPEL presentation consists of a time-ordered sequence of information items, where each item is associated with (at least) a mark and a channel (abstract output device to display the mark). In the CmapTools concept map representation of a SIMPEL presentation, a concept is used to describe an item. Channel information is included in the concept label. The mark attached as a resource to this concept represents the mark associated with the item (example, audio clip, image, or text selection). Directed links may be used to represent timing information and relative ordering of items. For example, the link between the BushText and MemexImage items means that MemexImage will be activated 8 seconds after BushText. The number 8 in the link may be considered as short hand for the phrase "plays 8 seconds before". This mapping enables representation of both sequential and parallel alignment of information items. Items beginning in parallel can be represented in multiple ways. For example, more than one mark resource could be attached to an item (represented by a concept). For more complex hypermedia-like presentations, the concept map could branch out into different options at a particular node, thus creating a hierarchical arrangement (where presentations may follow multiple paths).

3.2 Strand Maps

The Strand Map service enables users to build and navigate interactive visualizations of related learning goals, called *benchmarks*, and to request digital library resources aligned with benchmarks (Sumner, T., Ahmad, F. et al. 2005). Superimposed Strand Maps, an initiative by Portland State University, is aimed at exploring the use of superimposed information in an educational setting using a set of web-based tools for integrating strand maps into a curriculum (Delcambre, L. and Hanson, E. 2005). This will enable linking benchmarks to digital library resources at varying document granularities (e.g., linking a benchmark on database consistency to relevant chapters in an electronic book on database management systems). Figure 6 shows a section of a strand map, called "Weather and Climate". A strand map consists of node link representations illustrating a set of relationships between benchmarks organized around a topic. Each map contains vertical strands reflecting key ideas in that topic. Each strand is cross-referenced by grade levels.

Figure 7 shows one way of using a CmapTools concept map to represent the "Weather and Climate" strand map. The figure is a result of merging multiple snapshots of various actions on the concept map. Benchmarks are represented by concepts, and links represent relationships between benchmarks on a topic. Strands may be represented in multiple ways – by using color, by using one annotation for a set of concepts representing a strand, or by making use of a nested node (as shown in the figure). Grade levels can be represented in a similar manner, using color, annotations, or nested nodes (not shown in the figure). Each benchmark can have one or more marks associated with it, representing the digital library resource aligned with that benchmark.

4 Conclusion and Future Work

In this paper, we described how a concept mapping tool, IHMC CmapTools, may be enhanced below and above to facilitate representation and use of SI. We illustrated this by showing how concept maps in IHMC CmapTools may be used with two superimposed applications – SIMPEL and Strand Maps.

We believe that there are a number of benefits in this approach. Apart from providing more detailed information about a concept, a mark (to an information resource) may help in retrieving the original

information context of a particular concept. For example, a student may want to see the explanation of entities in the context of a paper that describes entity-relationship diagrams, and can use a mark accordingly. A key benefit in merging concept mapping and SI is that it will support the needs of two audiences: 1) the concept map user community – by providing a methodology to access resources at varying granularities, and 2) the SI user community – by giving them a new modeling tool to use and organize SI. A user would need to specify all marks (e.g., marked up regions, sub-document parts, anchors for hypermedia) only once, and add them as CmapTools resources, which later could be used by them or others (e.g., collaborators, students).

We are working on developing formal definitions of SI concepts. In doing so, we hope to be able to provide a common ground to study (among other things) SI, knowledge management (including concept map representations of knowledge), and annotations. We plan on further integration of SI functionality within CmapTools in order to treat marks as a separate resource type. This will enable access to the excerpt and context of the marked region from CmapTools (as is already available in another superimposed application called Sidepad (Murthy, S. 2005)). We also plan on conducting usability evaluations to validate and get feedback on the work described here.

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References

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Gómez, G., Eskridge, T. C., Arroyo, M. and Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. *In Proceedings of the First International Conference on Concept Mapping*, Pamplona, Spain.

Delcambre, L. and Hanson, E. (2005)."Superimposed Strand Maps." http://datalab.cs.pdx.edu/sidewalk/sistrand.php.

Maier, D. and Delcambre, L. (1999). Superimposed Information for the Internet. *In Proceedings of the WebDB Workshop*, 1-9.

Marshall, B., Zhang, Y., Chen, H., Lally, A., Shen, R., Fox, E. and Cassel, L. N. (2003). Convergence of knowledge management and E-learning: the GetSmart experience. *In Proceedings of the Proceedings of the 3rd ACM/IEEE-CS joint conference on digital libraries*, Houston, Texas, IEEE Computer Society, 135-146.

Murthy, S. (2005)."Sidepad User Guide." http://datalab.cs.pdx.edu/sparce/apps/Sidepad/userguide/index.html.

Murthy, S. and Maier, D. (2003). SPARCE: Superimposed Pluggable Architecture for Contexts and Excerpts. OGI CSE, Technical Report #CSE-03-010, ftp://ftp.cse.ogi.edu/pub/tech-reports/2003/03-010.pdf.

Murthy, S., Maier, D., Delcambre, L. and Bowers, S. (2004). Putting Integrated Information into Context: Superimposing Conceptual Models with SPARCE. *In Proceedings of the First Asia-Pacific Conference of Conceptual Modeling*, Denedin, New Zealand, 71-80.

Murthy, U., Ahuja, K., Murthy, S. and Fox, E. A. (2006). SIMPEL: A Superimposed Multimedia Presentation Editor and Player. *In Proceedings of the 6th Joint Conference on Digital Libraries*, Chapel Hill, USA, 377-377.

Sumner, T., Ahmad, F., Bhushan, S., Gu, Q., Molina, F., Willard, S., Wright, M., Davis, L. and Janée, G. (2005). "Linking learning goals and educational resources through interactive concept map visualizations." *International Journal on Digital Libraries* **5**(1): 18-24.

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FORMALIZING THE INFORMAL: A CONFLUENCE OF CONCEPT MAPPING AND THE SEMANTIC WEB

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Abstract. Concept Maps are seen as ways to conceptualize domains that can be comprehended within the human attention span, and are often based on terminologies arising in technical, scientific or engineering domains. We report on a set of related projects that go beyond this tradition in two ways: by connecting CmapTools to the new, machine-processable standard notations for formal Web meta-data (RDF and OWL), and by applying the resulting tools to the construction of Web markup for works of art. This domain provides a semantically-rich case study because descriptions of artwork inherently contain a mix of artifacts, some of which can easily be formalized (creator, title, creation date, etc.) and some of which express meanings about the work that are more difficult to formalize. Formalization of knowledge about works of art could benefit web developers by giving greater organization to these types of resources on the internet. It will also help foster the development of ontologies in other, similarly rich and challenging domains. A CmapTools extension called CmapTools Ontology Editor (COE) translates RDF and OWL to and from Concept Maps, providing a bridge between the worlds of human-oriented Concept Mapping and machine-oriented formal inference. Because of the strengths in CmapTools to provide a specific method for capturing meanings and concepts, we believe that the COE extension can provide the means for formalizing this conceptually challenging domain that involves an artist's interpretation of the intentions and motivations behind their artwork.

1 Introduction

The Semantic Web is often viewed as the "next generation" of the current World Wide Web (Berners-Lee, Hendler et al. 2001), which aims to create a simple way to express and store interchangeable data on the internet.

Because the volume of web resources (web pages, images, music, video, etc.) continues to increase exponentially, there is a recognized need for advanced strategies that will enable resources to be interpreted more logically by search engines and other intelligent agents. As such, there are many individuals and organizations beginning to explore the integration of semantic web strategies into their future web development activities.

The most widely accepted technique for employing semantic web technologies involves the use of a formalized language (OWL/RDF[1]) to 'markup' web resources with detailed descriptions of their content that can be more easily 'ingested' by computers. The resulting machine-readable markup is often referred to as an ontology. Ontologies must be created using a tightly controlled and elaborate syntax, and are required to satisfy many logical constraints, some of which may not be intuitively clear to human readers. Because of this, determining the content and structure of an ontology for a given domain requires an expert-level understanding of that content and its purpose.

CmapTools (Cañas, Hill et al. 2004) has been used to capture knowledge of human experts for use in training (Hoffman, Coffey et al. 2006), institutional memory preservation (Coffey, Eskridge et al. 2004), and in-the-field use (Coffey, Cañas et al. 2003). The method for eliciting this knowledge usually involves a moderator who questions and guides the expert and a mapper who documents the interview in one or more concept maps (Hoffman, Shadbolt et al. 1995; McNeese, Zaff et al. 1995). The result of this process, called a *knowledge model*, has proven to be easily navigated and understood by human users. However, because of their semantic expressivity, Concept Map-based knowledge models cannot easily be interpreted and made actionable by computers.

The work reported here is part of an effort to build a bridge between these two worlds (human comprehension and computational analysis), by casting OWL/RDF semantic web ontologies in the form of Cmap knowledge models, thereby making available to users the human-oriented clarity and conceptual organization provided by Cmaps, while retaining the ability to produce exact, formal ontologies for semantic-web markup.

[1] See http://www.w3.org/RDF/ and http://www.w3.org/2004/OWL/

We have developed an extension to CmapTools to facilitate this, called the CmapTools Ontology Editor, or COE[2] (Hayes, Eskridge et al. 2005). Human users of COE see and build knowledge models, and the software translates these to and from OWL/RDF ontologies when possible. COE can import any OWL/RDF formal ontology and display it as a Cmap, using a variety of notational conventions to render the idiosyncratic and formal content of the ontology in a reasonably human-readable format. It then allows users to edit and modify the Cmap in ways that conform as far as possible to the knowledge-model extraction method, and will automatically export the represented content into formal OWL/RDF for use as machine-interpretable semantic web markup. COE is operational at the beta-release stage and is currently being tested by various users in US government agencies. When completed, it will be made available as part of the basic functionality of the CmapTools software.

Warren is a practicing artist, photographer and technologist who maintains several websites containing a large number and variety of images using current web technologies. One goal of the Conceptual Art Mapping Project (CAMP) is to use COE to mark-up these image websites using OWL/RDF to describe both the images themselves and aspects of the ideas and processes that were involved in their creation and subsequent interpretation.

The formal specification of artistic work is a domain that is currently without a standardized ontology (van Ossenbruggen, Troncy et al. 2006). It is also a domain which might derive a great benefit from a more complete semantic web solution. Many artists and art organizations desire to organize and easily access their content, create presentations, sell to image banks or make available to editors, researchers or anyone interested in finding image content on the internet.

This paper reports on ongoing research into the techniques and methods for the conceptualization of relevant domain information using CmapTools, and the conversion of that information into machine interpretable, formalized ontologies using COE. The results are a confluence of informal knowledge specification and formal ontology design. Our ultimate goal is that an OWL/RDF formalized diagram of such informal and abstract knowledge will enable machine-readable markup for artists' work on the internet that is much more complete than traditional image annotations, and will hopefully result in a general purpose ontology for image makers.

2 Ontologies

Formal domain ontologies already exist. Some have the goal of providing an overarching framework for connecting disparate knowledge (Niles and Pease 2001), while others represent organized bodies of specialist scientific or technical knowledge. For example, the SWEET ontologies being developed at NASA JPL[3] represent concepts from the atmospheric and oceanographic sciences. New ontologies can build on existing ones, borrowing concepts and relations from any number of ontologies where convenient, and adding new concepts and relations where necessary. In this way, a common vocabulary for representing and annotating data can evolve. Although a large formalized ontology can be used for many purposes, the first benefit is often the ability to search more 'intelligently' through large corpora containing information from many sources.

Although common vocabularies for annotating images already exist, none of them address the artist's intent. Digital cameras store annotated technical data with each image at the time the image is captured, such as camera model, exposure settings, flash setting, date & time and other information (Committee 2002). Many image database and editing software tools contain annotation methods that draw from a number of vocabularies. IPTC[4] , Adobe XMP[5], Dublin Core[6], Visual Resources Association[7] can be used to tag the image with metadata describing properties such as creator, title, creation date, techniques and descriptions. All of these methods are based around keywords or 'tagging', which are enjoying a surge of popularity on image websites such as Flickr[8].

[2] http://cmap.ihmc.us/coe/
[3] http://sweet.jpl.nasa.gov/
[4] http://www.controlledvocabulary.com/imagedatabases/iptc_naa.html
[5] http://www.adobe.com/products/xmp/index.html
[6] http://dublincore.org/
[7] http://www.vraweb.org/vracore3.htm
[8] http://www.flickr.com

Even with the use of keywords and tagging, it should be noted that Google-type image search engines only look for the occurrence of a search term on a page containing the image or in the name of the image itself. Even annotation-based markup for images independent of page content would clearly help focus the work of such search agents. Search engines also have difficulties simply within the determination of keyword connections. For example: the words "chimp" "under" "large" "tree" may be used to tag an image, but it would not be clear that "large" refers to "tree" or to "chimp" unless the keywords were combined, but then it would be hard to determine that "large tree" is a type of "tree" (Schreiber, Dubbeldam et al. 2001).

There is also a distinction to be made regarding what type of work the image resource is; the work of a visual artist demands much more detail in its descriptions than work that is simply documentary in nature (images of real estate property, Uncle Bob in front of the Eiffel Tower, etc.) Much of an artist's intent may involve incidental aspects of the work in question rather than the obvious subject of the work. For example, the artistic impact of an image may be the mood set by the lighting conditions rather than the sailboat depicted in the image; more likely, it will be a combination of a variety of aspects of both the picture and the scene, and will involve analogies, metaphors, affective connotations, and other 'informal' connections between ideas.

With CAMP, we are specifically attempting to create markup that includes such things as: the artist's intent in creating the work; thematic elements in the work; the artist's interpretation of the work and elements of the work, and any influences upon their choice of medium or the style of the work.

3 Method

We began by creating unconstrained Concept Maps about a few of the artist's photographic images. As the domain expert, the artist, while gaining familiarity with CmapTools, used COE to represent factual information about each of the images, motivations behind the production of the works, and ideas involving artistic interpretation.

Early on it became clear that several kinds of information were being described in these maps, including descriptions of pictorial aspects of the image itself, descriptions of the techniques and materials used, of the physical scene being imaged, the circumstances of the picture-taking event (in the case of work produced through a photographic process) and of relationships between all of these - for example, that the time of the shoot influenced the quality of the light – and finally, more general interpretative information used in part to explain the titles of the pieces and how the interpretation relates to all the other elements. For the purpose of this paper, we selected one representational image from our initial test cases - a photograph titled "Confluence" - to illustrate our findings up to this point. The conceptual description has gone through many iterations. Some of these iterations were done using

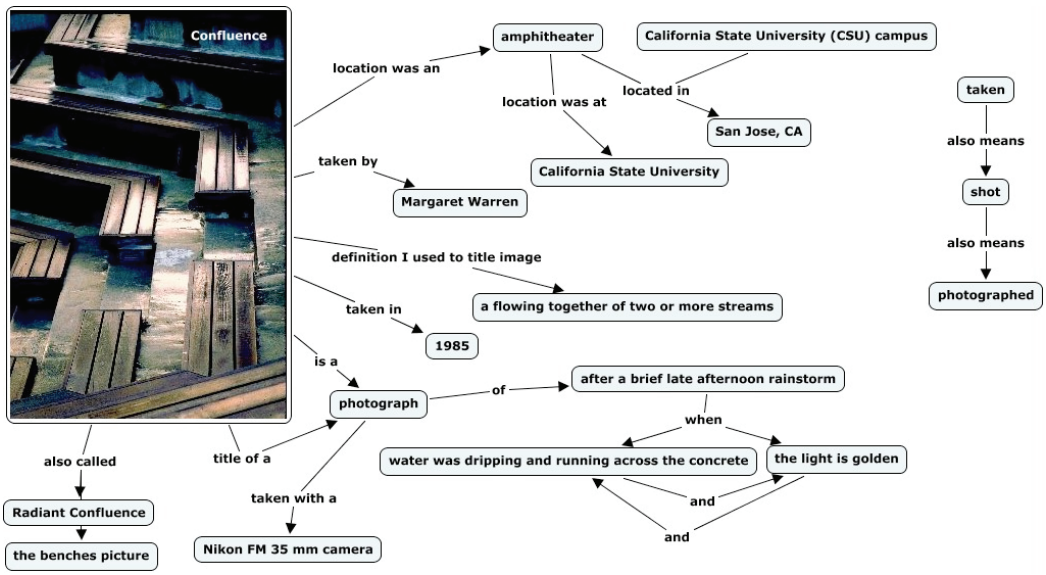


Figure 1. Initial "Confluence" Concept Map.

the PRESERVE interview sessions (Coffey and Hoffman 2003), while others were based on individual reflection and refinement on the part of the artist.

In the initial Concept Map, the artist was deliberately approaching the Concept Map from the point of view of describing the image itself, thereby making it the root node: it is a collection of statements made directly about the image. This initial Concept Map captures several types of information about the image: where and when it was taken, what kind of camera was used, other names for the image, what the image is of ("afternoon rainstorm," "golden light," "water dripping"), and how the title was derived from the image ("a flowing together of two streams").

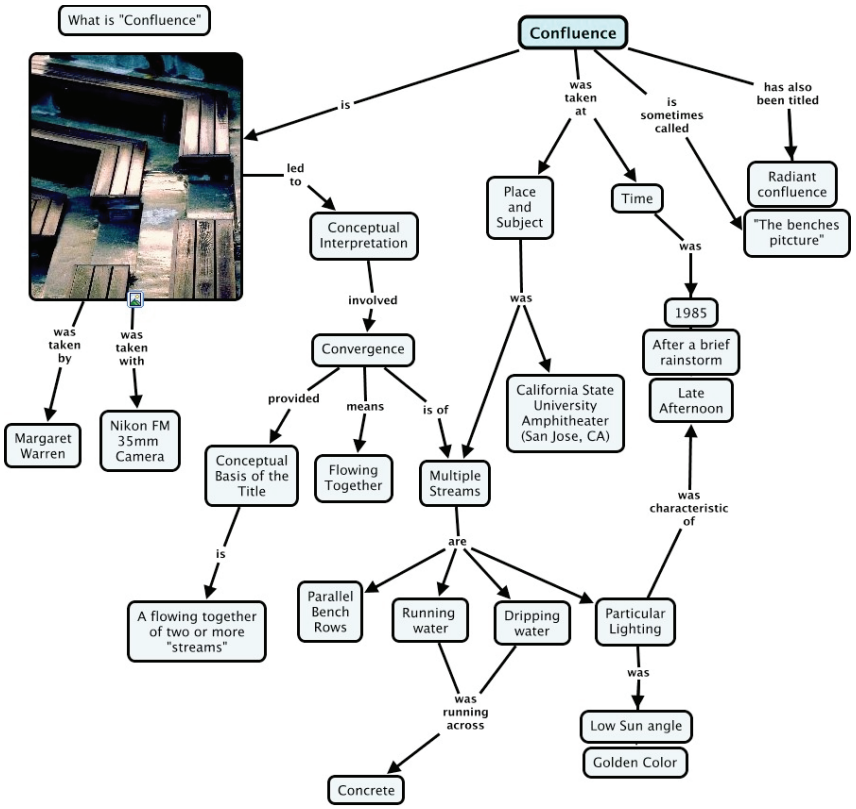


Figure 2. Second "Confluence" Concept Map.

The second Cmap was created through an interview session and uses the artist's title of the work as a root node as it also notably introduces the concepts "Conceptual Interpretation" and "Convergence" (see Figure 2.) This process of abstraction and explication continued with the development of the Concept Map shown in Figure 3, which abandoned the inclusion of the image altogether. This Cmap is organized with a series of major classifying nodes: "Temporal Elements," "Scenic Elements," "Pictorial Elements" and "Interpretive Elements," whose goal is to impose some order upon the various kinds of assertions represented by the 'interpretive' material of the previous Concept Map which reflects generalizations about the image-making process itself. We also introduced some semi-technical terminology to express the relationships involved. The 'educe' relation emerged from discussions at this point. The term "educe" (meaning "to draw, bring out; elicit") was suggested by the artist as a single word to replace a variety of formulations in an earlier version of the Concept Map, including 'give rise to,' 'produce,' 'lead to,' etc. Each of these had been used to talk about the relationship between a *physical* aspect of a depicted scene which was in some way responsible for a resulting *pictorial* element or feature. These pictorial elements were, to an experienced professional photographer, characteristic signs. For example, the angle of the sun in the late afternoon (a 'scenic element') educes a golden colored light (a 'pictorial element').

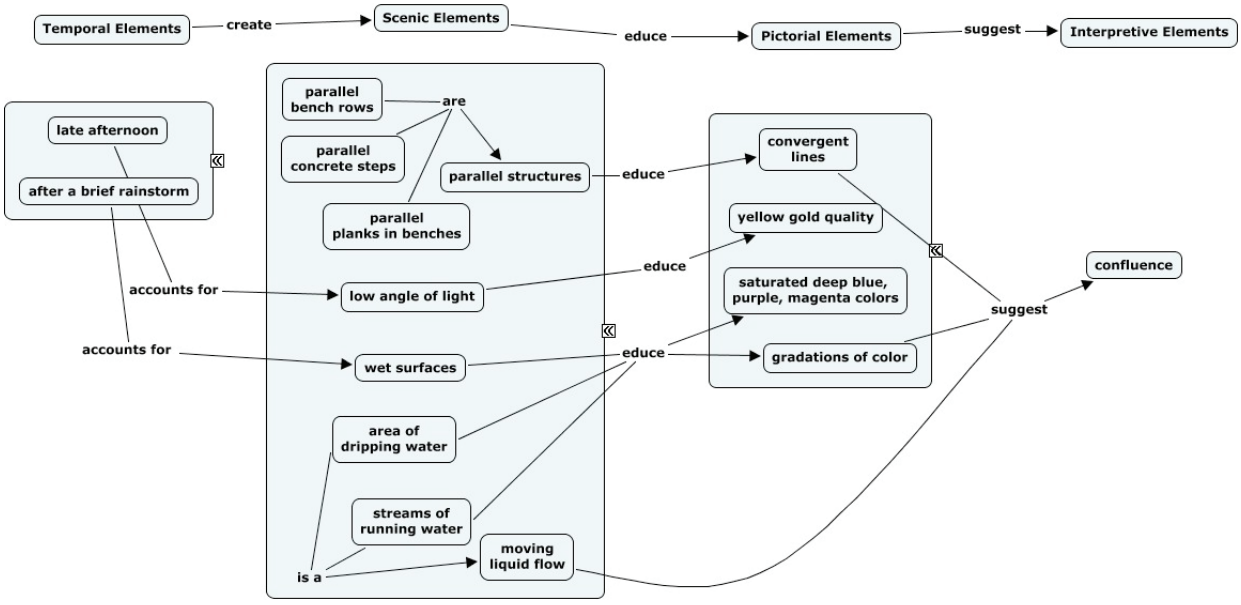


Figure 3. Third "Confluence" iteration, removing image entirely.

Why use a relatively obscure word to express an idea which can be said in a variety of ways already? The answer lies in a tension which runs through this project, between the *general* and the *particular*. One of our goals is to produce useful semantic markup for websites containing artistic images; semantic markup is of utility only to the extent that it uses concepts that are also used in other such markup. A purely private conceptual framework is of no use on the Web, where the ultimate aim is always to create and foster communication between disparate and distant web agents. We are therefore aiming to invent a 'standard' vocabulary which might be potentially used by a variety of Web markups. Such standardized vocabularies are critical to the success of Semantic Web applications. On the other hand, we wish to allow the artists to use their own terminology when describing their work, with relatively idiosyncratic and even private terms to express their intuitions. The expert knowledge used by artists may be informed by their academic background and training, but the creative process itself is less well articulated and less informed by any background theory than by the knowledge underlying expertise in scientific and engineering domains. Since there is no accepted terminology to express how the artist conceptualizes their artistic process, it is necessary to use metaphors, approximations, etc. Our approach is to deal at first with the particular, with the hope of being able eventually to abstract general concepts from it and incorporate these into a useful middle-level 'artistic interpretation' ontology that will enable many artists to annotate their work using a common vocabulary, and enable computers and people and software agents to collaboratively make use of them. Rather than attempt to *impose* any kind of aesthetic theory at first, we hope to *discover* some common structure or conceptual themes from a large number of detailed analyses of particular images. We believe that this notion that we have labeled 'educe' is an example of a central concept in image interpretation. Ironically, providing it with a special 'formal' label is one way to encourage its recognizable use in markup, essentially by providing a single name for a relatively fine-grained concept.

It is interesting also to examine Figure 3 from a Concept Mapping point of view, rather than from an ontology development point of view. In this figure, we have introduced four new concepts concerning the elements of an artistic work and have grouped different aspects of our concept map description of "Confluence" under their corresponding elemental type. Novak's (1998) explanation of Concept Mapping in terms of Ausubel's assimilation learning theory could just as neatly apply to our work here developing ontologies, which we find encouraging. In particular, introducing superordinate concepts, progressively differentiating existing knowledge, and integrative reconciliation are all theoretical principles that are clearly evident in the successive iterations of the Concept Maps. Being able to transfer the theoretical foundation of Concept Mapping to building ontologies is an added benefit of the COE approach to ontology development.

4 Moving from informal to formal

The last stage of our process is converting the Concept Map into a form that can be exported into OWL/RDF. This is trivial to do poorly, but difficult to do well. A trivial translation simply renders the Concept Map into RDF so that each node-arc-node combination becomes an RDF triple. However, the result is 'shallow' since most of the significant meaning is buried in the node and arc labels, and hence is invisible to a semantic web reasoner. A deeper analysis is required in order to more adequately represent the meaning of phrases used as node and arc labels. For example, our Concept Map contains a concept "*yellow gold quality"* which refers to the quality of the light in the picture. Clearly, this has something to do with color. We could naïvely transcribe this label into an RDF 'label' - which must be a Web Universal Resource Identifier, and so might become *http://purl.oclc.org /CAMP/concepts/colors/yellow_gold_quality*. However, there is nothing in the ontology that records the fact that this is a color concept, nor is there any information about colors; for example, that gold is complementary to blue.

Such classifications of concepts and relations between them are what OWL is designed to record, but putting this information into the Concept Map requires more work to be done. We expect this to be an incremental process, since the most useful structure of classifications and concept relationships can emerge only by a process of induction applied to a number of Concept Maps. An interim product resulting from our single Cmap is shown in Figure 4. The top part is an OWL-ized version of the Cmap itself, while the other parts of the Cmap record a variety of background information and links to other, existing, ontologies written using COE notational conventions. Concepts labeled with 'naïve' phrase transcriptions (like _this) are intended as placeholders which will require more attention later.

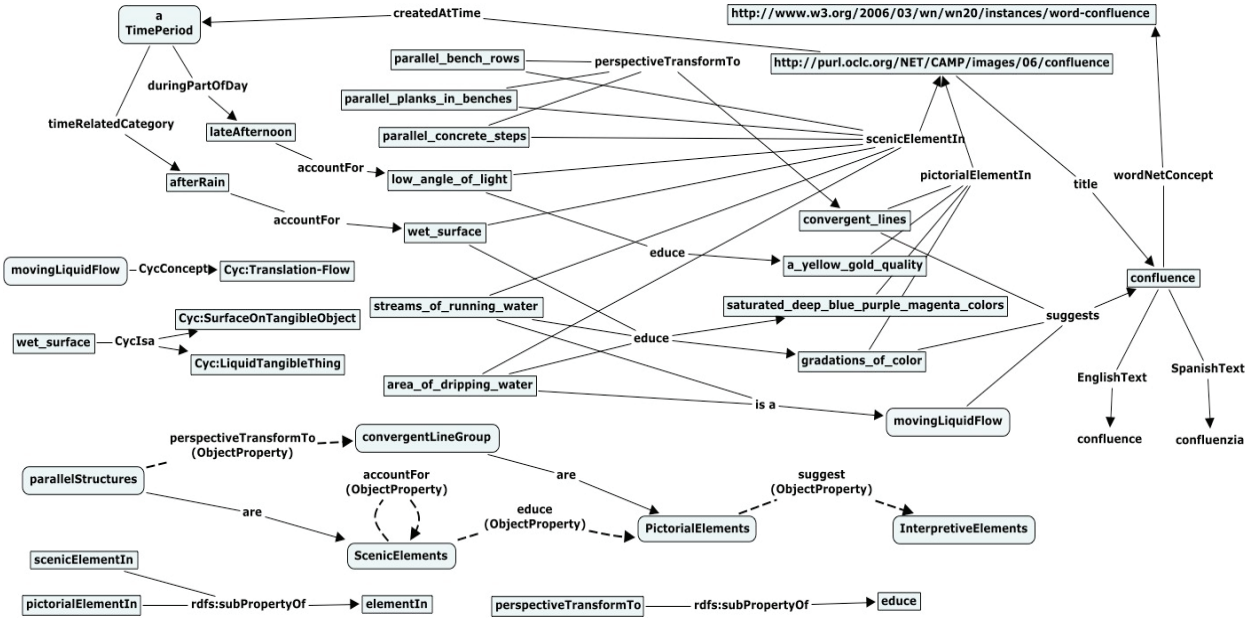


Figure 4. The formalized "Confluence" Concept Map.

Finding what one might call 'OWL structure' in the Concept Map requires paying close attention to categories (or classes) and properties. OWL is based on a global picture which regards *individuals* as categorized or classified in various ways into *classes*, and which have *properties* whose values are other individuals. In the above example, the fact that *yellow_gold* is a color would be a classification, and color-complement would be a property (of yellow, with value blue; of red, with value green, etc.) Much of the craft of writing adequate ontologies lies in making a deft choice of classifications and properties; and this is still very much an art rather than a science. For example, our conceptual analysis seems to have identified categories of 'pictorial element' and 'scenic element,' suggesting that 'elements' are the primary individuals in this domain. But what exactly *are* these "elements"? They seem to include things which one would intuitively think of as properties or facts (that some lines are parallel), and they seem to be very eclectic, including color, geometry and properties of surfaces. We anticipate that finer and more detailed categories will emerge as we proceed - they are in any case of use only insofar as they serve to state some general regularities which apply to more than one image - but the appropriate ontological strategy at this early stage is a kind

of principled agnosticism, to try to only make very 'large', weak generalizations, such as in our case that between *picture* and *scene*, and then expect more detailed structure to emerge from more examples. Already, we have noted that there seemed to be a single relationship called *educe*. (OWL allows us to use a property as a kind of classification of other properties, called its subproperties, and we expect *educe* to have many subproperties which have more precise meanings, such as *perspectiveTransformTo*.)

The same intuitive content can be encoded into a notation like OWL in a large number of different ways, and the choice among them is not always obvious (van Ossenbruggen, Troncy et al. 2006). For example, in an early version we had classes of 'picture elements in the image,' until we realized that (of course) such classes are of use only if they can be related to the particular image. Therefore, we decided to treat these as properties of the elements, with the image as value. This allows a single element to figure in more than one image. The art of compiling useful ontological markup lies in making such decisions well; but these go beyond the usual process of building a conceptual model, and require attention to much finer-grained conceptual distinctions.

The 'background' information in the final Cmap included general facts about categories and properties and also links to similar (perhaps identical) concepts in other published ontologies. The general facts, which have many variations, allow a Semantic Web reasoner to draw simple conclusions from the facts at its immediate disposal. For example, our Cmap does not assert directly that *parallel_bench_rows* is classified as a *ParallelStructure*, but this follows from the background fact that the latter is the 'domain' of the property *perspectiveTransformTo*, which is applied to the former in the Cmap (indicated by a bold dashed line.) Other facts establish subcategory relations and relationships between classes and property values. The relatively few background facts we have described here are sufficient to generate enough conclusions to increase the size of the Concept Map by a factor of approximately five.

Making links to existing published ontologies is a critical for the success of the Semantic Web. Such re-use means that concepts of broad utility become articulated into more and more pieces of available knowledge, increasing their utility for search and inference. In our example, the links are to two widely cited ontologies: WordNet (W3C 2004), which contains synonym and hypernym relationships for all English nouns, and the OpenCyc knowledge base, which contains a large number of 'natural' concepts under a large number of headings. It is notable that many of our concepts, even from this one image, seem to have no exact correspondence to any published concept corpora. There are, for example, several 'standard' temporal ontologies, which provide for detailed time attributions and define concepts such as millisecond or international time zone; but none of them contain concepts such as 'late afternoon' or 'early morning,' which are qualitative rather than numerical, and which are relevant to appearance (as in 'early morning light') rather then time-charting. Cyc has an elaborate classification of physical shapes and surfaces, but it is oriented to physical thinking, rather than to optical qualities of surfaces: Cyc for example 'knows' that touching a wet surface makes the toucher wet, but has no way to infer that a wet surface is typically reflective. We expect that we will be obliged to develop 'artist-quality' ontologies for such matters as kinds of lighting, colors, relevant atmospheric and surface forms, etc., as the project proceeds.

The export facility of COE will output as much of the Concept Map as possible into structured OWL, and translate the rest into unstructured RDF when possible, or simply ignore it. The result of exporting our map is an RDF/XML file. A Concept Map also contains a great deal of other information, including the actual layout of the nodes on the page, and may contain annotations in the form of isolated nodes containing text, or 'sticky notes'. We call Concept Maps that contain both such informal Concept Map information and ontology information *Combination Cmaps*. The informal information may be placeholders that are awaiting translation into OWL/RDF, or they may be segments of Concept Maps that are used to explain particular pieces of OWL/RDF representation. The explanations may also be used to contextualize the ontology for human readers, so that potential users can get a better understanding of the original intent of the ontology author, and where and why the ontology may be useful. We are just beginning to discover the utility of Combination Cmaps, but we are already anticipating that they will benefit ontology development through greater understandability and collaboration.

5 Conclusions

Building a bridge between knowledge models, which reflect human learning, and formal ontologies, which can support machine inference, is challenging but also necessary and important. We cannot claim to have fully bridged this gap. While we have found that people are able to construct COE maps after a few hours of training, exporting these maps to useful OWL/RDF generally requires iterative development and specialized background knowledge to

interpret properly. In addition, our longer-term goal requires us to formalize even more human intuition in the form of ontologies that define the meanings of vocabularies which can describe aspects of pictures and artwork that are relevant to artist's concerns. Such ontologies do not yet exist, but experience with other areas of ontology development leads us to be guardedly optimistic that it is possible in a reasonable timescale.

One aspect of the CAMP project is as a test-bed for educing improvements to the GUI design of tools such as COE. Already, for example, it is clear that it would be desirable to make assertions about areas or regions of a picture rather than relating all markup to the entire image. Experience with CAMP also suggests several improvements to the COE interface to allow the compact representation of commonly used descriptive patterns in RDF/OWL.

The CAMP project is also a 'forcing function' in a larger sense. There have been many attempts to create 'common sense' or 'high-level' ontologies intended to provide concepts for representing intuitive or informal knowledge. However, even the most ambitious of these (such as Cyc) contain many concepts with a distinctly 'technical' flavor, more suited to expressing ideas in engineering or mathematics than those that seem to form the everyday substance of human experience and intuitive thought. Our intended domain of application is stubbornly resistant to any pressures to 'technicalize' its conceptual vocabulary, which is both part of its interest and what makes it challenging.

Finally, we expect and hope that the combination of tools, vocabularies, ontologies and representational ideas which emerge from CAMP and COE will be a useful resource for artists, archivists and anyone concerned with cataloging, writing about or searching for images on the Web.

6 References

Berners-Lee, T., J. Hendler, et al. (2001). The semantic web. *Scientific American*. 284**:** 34-43.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W., A. J. Cañas, et al. (2003). Knowledge Modeling and the Creation of El-Tech: A performance support and training system for electronic technicians. *Expert Systems with Applications* 25(4): 483-492.

Coffey, J. W., T. C. Eskridge, et al. (2004). A Case Study in Knowledge Elicitation for Institutional Memory Preservation Using Concept Maps. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W. and R. R. Hoffman (2003). Knowledge modeling for the preservation of institutional memory. *Journal of Knowledge Management* 7(3): 38-49.

Committee, T. S. (2002). *Exchangeable image file format for digital still cameras: Exif Version 2.2.* from http://www.exif.org/Exif2-2.PDF.

Hayes, P., T. C. Eskridge, et al. (2005). Collaborative knowledge capture in ontologies. *Proceedings of the 3rd International Conference on Knowledge Capture*. Banff, Alberta, Canada, ACM Press.

Hoffman, R. R., J. W. Coffey, et al. (2006). A method for eliciting, preserving, and sharing the knowledge of forecasters. *Weather & Forecasting* 21: 416-428.

Hoffman, R. R., N. Shadbolt, et al. (1995). Eliciting knowledge from experts: A methodological analysis. *Organizational Behavior and Human Decision Processes* 62: 129-158.

McNeese, M., B. S. Zaff, et al. (1995). AKADAM: Eliciting user knowledge to support participatory ergonomics. *International Journal of Industrial Ergonomics* 15: 345-363.

Niles, I. and A. Pease (2001). Towards a standard upper ontology. *Proceedings of the International Conference on Formal Ontology in Information Systems* ,Volume 2001. Ogunquit, Maine, USA, ACM Press.

Schreiber, A. T., B. Dubbeldam, et al. (2001). Ontology-based Photo Annotation. *IEEE Intelligent Systems* 16(3).

van Ossenbruggen, J., R. Troncy, et al. (2006). *Image annotation on the Semantic Web*. from http://www.w3.org/2001/sw/BestPractices/MM/image_annotation.html.

W3C (2004). *Wordnet in RDF and OWL*. http://www.w3.org/2001/sw/BestPractices/WNET/wordnet-sw-20040713.html.

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Proc. of the Second Int. Conference on Concept Mapping
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HOW COMPASS SUPPORTS MULTI-FEEDBACK FORMS & COMPONENTS ADAPTED TO LEARNER'S CHARACTERISTICS

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Abstract. In this paper, we present the feedback process of a web-enabled concept mapping learning environment, referred to as COMPASS. Different forms of feedback (text-, graphical- and dialogue-based) are supported and multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available, in terms of delivering individualized feedback. The ITRFC aim to stimulate learners to reflect on their beliefs, to guide and tutor them towards the achievement of the learning outcomes addressed by the concept mapping activity, to inform them about their performance and to serve learner's individual preferences and needs. The adaptive functionality of the feedback process is based on learner's knowledge level, preferences and interaction behaviour and is implemented through (i) the technology of adaptive presentation that supports the provision of alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components in the dialogue-based form of feedback. Moreover, COMPASS gives learners the possibility to have control over the feedback presentation process by making the desired selections.

1 Introduction

Feedback is considered as a key aspect of learning and instruction (Mory, 1996). Effective feedback aims to (i) assist learners in identifying their false beliefs, becoming aware of their misconceptions and inadequacies, and reconstructing their knowledge, (ii) help learners to determine performance expectations, identify what they have already learned and what they are able to do, and judge their personal learning progress, and (iii) support learners towards the achievement of the underlying learning goals (Mory, 1996; Mason and Bruning, 2001). Thus, feedback should guide and tutor learners as well as stimulate and cultivate processes like self-explanation, self-regulation, and self-evaluation, which require reflection (Chi et al., 1994). Moreover, feedback should be aligned, as much as possible, to each individual learner's characteristics, since individuals differ in their general skills, aptitudes and preferences for processing information, constructing meaning from it and/or applying it to new situations (Jonassen & Grabowski, 1993).

In the field of computer-based concept mapping, recently developed environments attempt to embed a scheme for feedback provision. Specifically, in the Reasonable Fallible Analyser (RFA) (Conlon, 2004), feedback is provided about the quantitative score of learner's map accompanied with explanation of how the score is obtained. For concepts and propositions that learner believes that have not been properly credited, a dialogue between the RFA and the learner could begin. Also, hints concerning missing concepts and links as well as incorrect relationships are provided. The system proposed by Cimolino et al. (2003) provides hints (feedback strings defined by the expert) about specific errors such as missing propositions. In (Chang et al., 2001), the system gives appropriate hints after the analysis of learner's map; the hints concern specific types of errors and are provided in the form of partial propositions (e.g. for an incorrect concept the hint has the form "*Bytes* are the basic measurement unit of ???). The networked knowledge mapping system of Hsieh and O' Neil (2002) provides knowledge of response feedback (i.e. a list indicating whether each concept on a map needs a little, some or a lot of improvement) and adapted knowledge of response feedback (i.e. the same information as knowledge of response complemented with information about how student had improved on his/her map since the last time s/he got feedback and a description of the most useful way to use this information). From the literature review, it becomes obvious that feedback in the aforementioned environments has mainly an informative and guiding orientation and is tailored to specific common errors identified on learner's concept map after the comparison of learner's map with the expert map. Moreover, none of the systems takes into account learners' individual differences.

In this line of research, we developed COMPASS (COncept MaP ASSessment & learning environment) which provides feedback aiming to inform learners about their learning progress, guide and tutor them in the direction of enriching/reconstructing their knowledge, support reflection and accommodate their learning needs and preferences. To this end, COMPASS supports various feedback forms (i.e. text-, graphical- and dialogue-based form) and multiple feedback components (i.e. Informative, Tutoring and Reflective Feedback Components (ITRFC)). In dialogue-based form, the ITRFC are structured in different layers to support the gradual provision of the right amount of feedback information. The adaptive functionality of the feedback process is implemented through (i) the technology of

adaptive presentation that supports the provision of the alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components (in dialogue-based form). Learner's knowledge level, preferences and interaction behaviour are used as a source of adaptation. Additionally, learners have the possibility to intervene in the feedback presentation process by selecting the preferred feedback form and component, in accordance with their own perceived needs and desires. The rest of the paper is structured as follows. In Section 2, an overview of COMPASS is presented. In section 3, the feedback process is described in terms of the different forms of feedback supported, the ITRFC provided, the adaptive functionality of the feedback process and the learner support and control offered. The paper ends with the main points of our work and our near future plans.

2 An Overview of the COMPASS Environment

COMPASS (available at http://hermes.di.uoa.gr/compass) is a web-enabled concept mapping learning environment, developed at the Educational & Language Technology Laboratory of the Department of Informatics & Telecommunications at the University of Athens. COMPASS aims to assess learner's understanding as well as to support the learning process by employing a variety of concept mapping activities, applying a scheme for the qualitative and quantitative estimation of learner's knowledge and providing different informative, tutoring and reflective feedback components, tailored to learner's individual characteristics and needs (Gouli et al., 2004b).

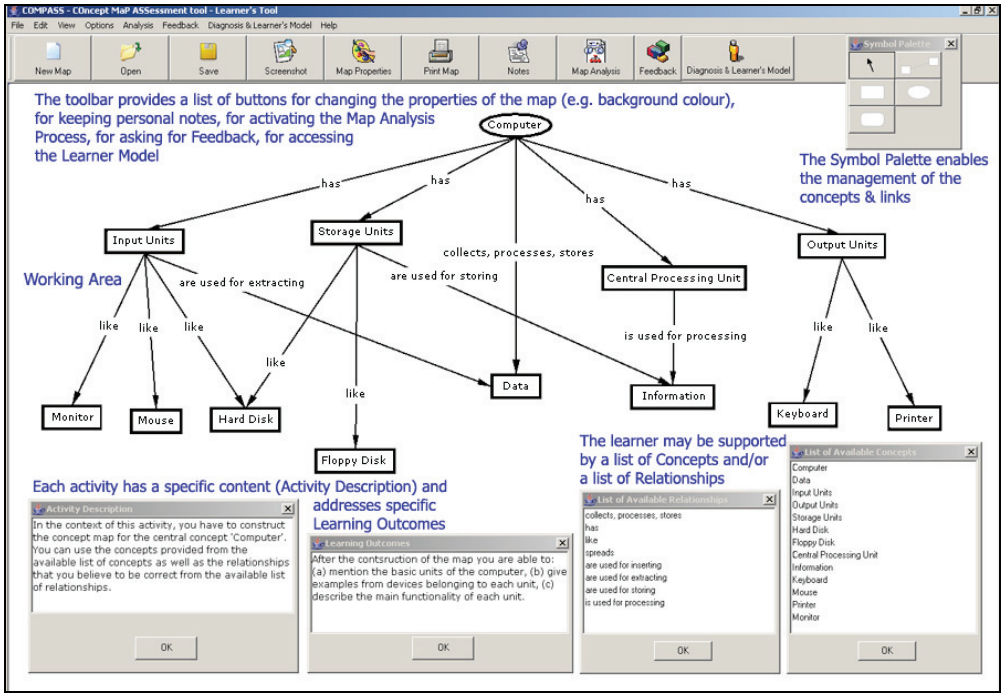


Figure 1. The main screen of COMPASS. The Working Area presents a concept map constructed by a learner in the context of a construction task supported with a list of concepts and relationships. The specific task is one of the activities provided in the context of the learning goal "The Computer Architecture".

Based on the learning goal that learner selects, which corresponds to a fundamental topic of the subject matter, COMPASS provides various activities, addressing specific learning outcomes. Depending on the outcomes, the activities may employ different concept mapping tasks, such as the construction of a map, the evaluation/correction, the extension and the completion of a given map; each of these tasks provides a different perspective of learner's understanding (Ruiz-Primo & Shavelson, 1996). The concept mapping tasks are characterized along a directedness continuum from high-directed to low-directed, based on the context of the task and the support provided to learners; learners may have at their disposal a list of concepts and/or a list of relationships to use in the task and/or may be free to add the desired concepts/relationships. The provided lists may contain not only the required concepts/relationships but also concepts/relationships that play the role of distracters. In Figure 1, the main screen of COMPASS is shown. It consists of (i) the menu and toolbar, which provide direct access to several facilities such as

the provision of feedback and the analysis of the map, and (ii) the Working Area, on which the central concept (in case of the construction) or the working map (constructed by the teacher) (e.g. the map that learners have to evaluate/correct, or extend or complete) are presented.

Depending on the attributes of the activity, learner's concept map may be assessed either automatically by COMPASS, or by teacher or by peers through the PECASSE (PEer and Collaborative ASSessment Environment) environment (available at http://hermes.di.uoa.gr:8080/pecasse). The analysis of the map (i) is based on the assessment of the propositions according to specific criteria concerning completeness, accuracy, superfluity, missing out and non-recognizability, (ii) results into the identification of specific error categories, and (iii) is discriminated in the qualitative and the quantitative analysis. The qualitative analysis is based on the qualitative characterization of the errors and aims to contribute to the qualitative diagnosis of learner's knowledge; that is learner's incomplete understanding/beliefs and false beliefs. The quantitative analysis aims to evaluate learner's knowledge level on the central concept of the map and is based on the weights assigned to each error category as well as to each concept and proposition that appear on expert map. The weights are assigned by the teacher and reflect the degree of importance of the concepts and propositions as well as of the error categories, with respect to the learning outcomes addressed by the activity. In this way, the teacher has the possibility to personalize the assessment process. An analytical description of the assessment scheme incorporated into COMPASS accompanied with an example is given in (Gouli et al., 2005). The results derived from the map analysis are represented to learners in an appropriate form during the feedback process.

3 The Feedback Process in COMPASS

The feedback provided in COMPASS aims to serve processes of assessment and learning by (i) informing learners about their performance, (ii) guiding and tutoring learners in order to identify their false beliefs, focus on specific errors, reconstruct their knowledge and achieve specific learning outcomes addressed by the activity/task, and (iii) supporting reflection in terms of encouraging learners to "stop and think" and giving them hints on what to think about. Different forms of feedback are supported with respect to the addressed learning outcomes and learner's preferences: text-based, graphical-based and dialogue-based form. Multiple Informative, Tutoring and Reflective Feedback Components (ITRFC) are available during the feedback process in an attempt to stimulate learners to reflect on their beliefs, to guide and tutor them towards the achievement of the learning outcomes, to inform them about their "current" state and to serve learners' individual characteristics. Below, we discuss in more detail the available ITRFC, the dialogue-based form of feedback, the adaptive functionality of the feedback process and the learner control and support offered during the elaboration of the activity.

3.1 Informative, Tutoring and Reflective Feedback Components

The term ITRFC refers to the different components of feedback, which exploit various feedback types reported in literature and offer different levels of verification and elaboration in order to serve learners' individual preferences and needs. The ITRFC are classified in the three feedback types, presented in Table 1.

Feedback Type	Feedback Component	Available in …
Informative *aims to inform learner about the correctness of his/her answer and his/her performance*	Correctness-Incorrectness of Concept/Proposition & Type of Error (CI-TE): *informs learner whether his/her represented concept/ proposition is correct/ incorrect, and in case of a false belief (i.e. proposition) which is the type of the error.*	*Text-based* form of feedback (see Figure 2). *Graphical-based* form of feedback. The learner's map is graphically annotated; different annotations are used for each error category and for complete-accurate propositions. *Dialogue-based* form of feedback (available at stage 1, see next section).
	Correct Proposition (CP): *supplies learner with the correct proposition represented on expert map.*	*Dialogue-based* form of feedback (available at stage 1 or 3, see next section).

	Expert Map (EM): *supplies learner with the expert map itself.*	*Graphical-based* form of feedback.
	Performance Feedback (PF): *informs learner about his/her current state, that is (i) learner's knowledge level,(ii) learner's incomplete understanding and false beliefs, (iii) learner's performance during the elaboration of the activity (i.e. the progress of learner's knowledge level, as this is recorded after the map analysis), and (iv) statistics such as the number of times that map analysis performed, the number of times that feedback was asked, the total time spent for the accomplishment of the activity/task, the learner's preferences on feedback components during the elaboration of the activity.*	*Text-based* form of feedback. *Graphical-based* form of feedback depicting learner's progress during the elaboration of the activity.
Tutoring *aims to tutor learner by enabling him/her to review learning material relevant to the attributes of the correct concept /proposition*	Tutoring Feedback Units (TFU): *supply learners with learning material for the concepts represented on expert map and/or the concepts included in the provided list of concepts. The TFU are structured in two levels: the learning goal level and the activity level. The material of the learning goal level is available for all the activities for which the specific concept is represented whilst the material of the activity level is available only for the specific activity. The TFU are associated with various types of knowledge modules such as a description or a definition of the concept under consideration, an image, an example, a counterexample, a task or a case. The different types of knowledge modules aim to serve learners' individual preferences and to cultivate skills such as critical thinking, ability to compare and combine alternative tutoring feedback units etc.*	*Text-based* form of feedback. *Dialogue-based* form of feedback (available at stage 2, see next section).
	Explanation of the Proposition (EP): *explains why the false belief (proposition) is wrong or why the correct belief is correct.*	*Dialogue-based* form of feedback (available at stage 2 or 3, see next section).
Reflective *aims to promote reflection and guide learner's thinking, explore situational cues and underlying meanings relevant to the error identified*	BP-RW Belief Prompt-Rethink Write (BP-RW): *consists of (i) learner's belief in order to bring learner "in front" of his/her belief and encourages him/her to rethink his/her belief, and (ii) a prompt to write any keywords and/or explanations concerning his/her belief.*	*Dialogue-based* form of feedback (available at stage 1, see next section).
	Reflective Questions (RQ): *give learner hints, in the form of questions, to rethink and correct the identified false belief (proposition). The RQ may refer to the errors identified (error-related RQ) or may model a human teaching strategy (Collins, 1987) (inquiry-related RQ). The form of the error-related RQ is differentiated according to the error categories that may be identified on map. For example, an error-related RQ may ask learner to rethink the relation between the two concepts or the position that a concept is placed or how a concept can be added to the map. The inquiry-related RQ may give learner a consequence of his/her false belief and prompts him/her whether s/he insists on his/her belief or may suggest an incorrect hypothesis and ask learner to think what could be happened or may ask learner to consider an alternative prediction, etc. The inquiry-related RQ are available for specific propositions that the teacher anticipates errors/false beliefs from his/her experience and aims to bring learner confronting with information that help him/her to rethink his/her belief.*	*Dialogue-based* form of feedback (available at stage 2, see next section).

Table 1: The Informative, Tutoring and Reflective Feedback Components available in the feedback process.

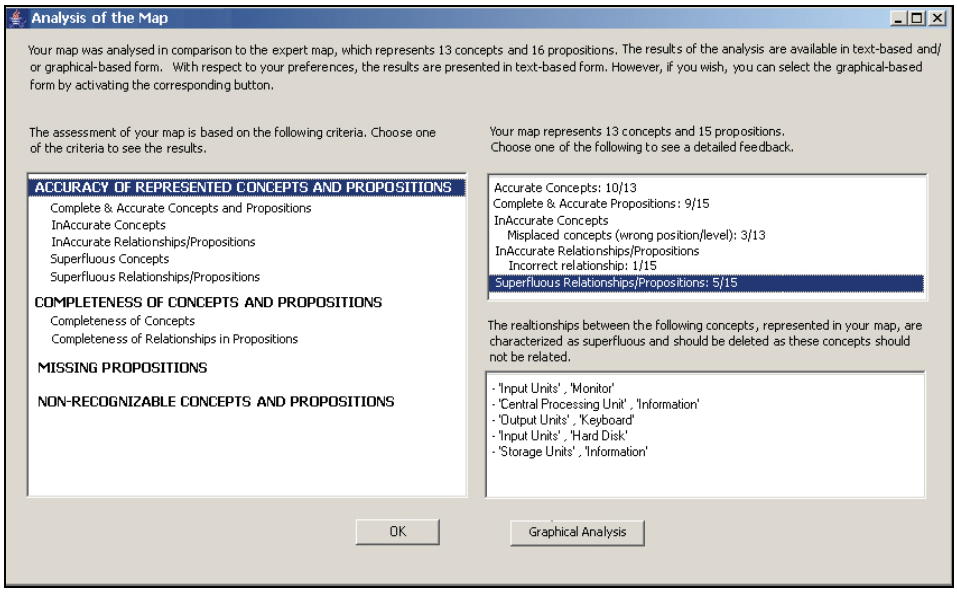


Figure 2. The results, in text-based form, derived from the analysis of the learner's map depicted in Figure 1. The learner has selected to see the results concerning the criterion of "Accuracy of Represented Concepts and Propositions" (left window), and more specifically the results for superfluous relationships/propositions (right up window). The corresponding CI-TEs are presented in the right bottom window.

3.2 Providing Feedback in Dialogue-based Form

In dialogue-based form, the available feedback components are structured in different layers with respect to the stages of the dialogue process and a stepwise presentation of the components is realized, following their layered structure. The stepwise presentation aims to provide gradually the appropriate amount of feedback information to each learner, and enable learners at each step to exploit the feedback information and return to his/her concept map in order to correct the identified false belief. On the basis of the qualitative characterization of each proposition represented on learner's map after the map analysis, the dialogue between COMPASS and learner is as follows:

- if a proposition is characterized as *complete and accurate* and the teacher has defined that it should be explained by the learner, then COMPASS presents learner's belief and asks him/her to give a description of the concepts included in the proposition and explain in few words why s/he believes the specific proposition (provision of BP-RW) (stage 1). After the learner saves his/her description, an explanation of the proposition defined by the expert is available (provision of EP) (stage 2). The learner has the possibility to change his/her description as many times s/he wishes.
- if a proposition is characterized as *non-recognizable*, COMPASS informs learner about the concepts and/or the propositions that were not assessed (provision of CI-TE), provides the concepts/propositions from the expert map that could substitute the non-recognizable ones (provision of CP) and asks learner to rethink/correct them (stage 1).
- if a proposition is characterized as *inaccurate (inaccurate-superfluous)*, the dialogue is carried out in 3 stages.
  - The *1st stage* aims at enabling learner to rethink his/her beliefs and getting into a self-explanation process in order to identify any errors made mainly by accident. Thus, COMPASS informs learner about the inaccuracy of the concept or the proposition under consideration and asks him/her to describe in few words the concept(s) included in the proposition (provision of BP-RW).
  - The *2nd stage* aims to (i) guide learners and redirect their thinking by giving them a hint, and (ii) tutor learners by enabling them to review learning material relevant to the inaccurate concepts/propositions. At the beginning COMPASS gives learner hints in the form of questions on the basis of the error identified (provision of error-related RQ). For example for the proposition "Input Units are used for extracting Data", depicted on the map of Figure 1, which is characterized as inaccurate (incorrect relationship error), the following error-related RQ is provided: "Do you really believe that the concepts [Input Units] and [Data] are related with the specific relationship, forming the proposition [Input Units] are used for extracting [Data]?". Following, the learner may select to follow up with inquiry-related RQ (if there are available) or has the possibility to select for study the available tutoring feedback units (TFU). In the latter case, the

selected TFU in conjunction with the corresponding error-related RQ are provided. Each TFU may be accompanied with additional material and explanations. For example, for the aforementioned proposition, if the learner selects to follow up with inquiry-related RQ, the following RQ is provided "You believe that [Input Units] are used for extracting [Data]. If it is true then with the Mouse, which is an Input Unit, we could extract Data. How is it possible to extract Data using Mouse? Do you insist on your belief?". The inquiry-related RQ are defined for specific propositions that the teacher anticipates errors/false beliefs from his/her experience and are presented following a pre-specified order (defined by the teacher).

- *The 3rd stage* aims to inform learner about the correct belief and to provide explanations of why his/her belief is incorrect. COMPASS provides learner with the correct proposition(s) (CP) and with the explanation of the proposition (EP) (if supported).

In each stage of the dialogue, learner is free to choose any of the already provided system's proposals from previous stages. An example of the stages of the dialogue is depicted in Figure 3.

- if a proposition is *incomplete or missing*, the dialogue is generated in 2 stages similar to the 2nd and the 3rd stages mentioned above (the inquiry-related RQ and the EP are not supported).

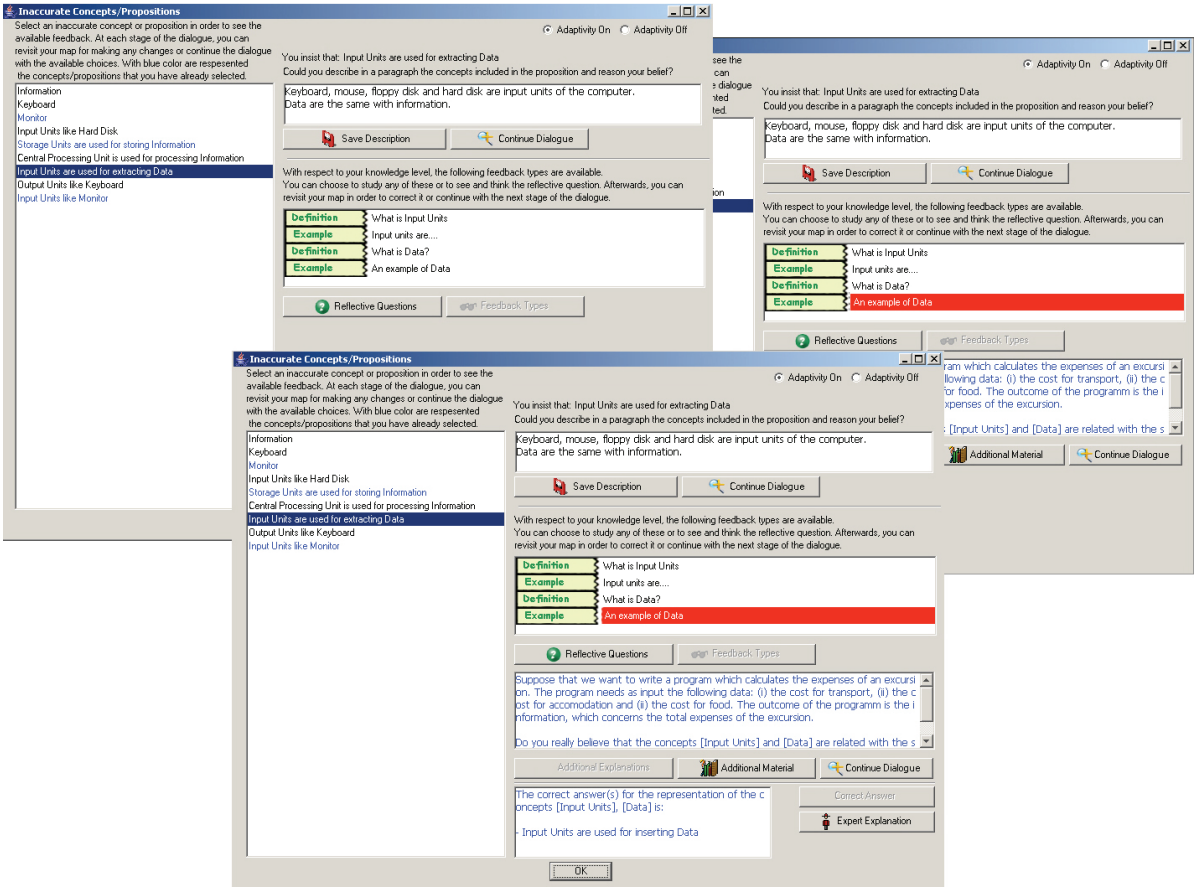


Figure 3. The stages of the dialogue for Inaccurate Concepts/Propositions. For the false proposition "Input Units are used for extracting Data", which is depicted in Figure 1, the learner in the first stage of the dialogue has given a description of the concepts included in the proposition and has chosen to Continue the Dialogue. Then the available feedback types, with respect to his/her knowledge level, are presented (first figure at the left). Following, the learner has selected to study the knowledge module "An example of Data" and the corresponding TFU in conjunction with the error-related RQ are presented in the second figure at the right. Afterwards, the learner has chosen to continue the dialogue and the correct answer for the specific proposition, with respect to his/her preferences, appears (centred figure).

3.3 Supporting Adaptation in the Feedback Process

The adaptive functionality of COMPASS is reflected to the personalization of the provided feedback in order to accommodate a diversity of learners' individual characteristics and is implemented through (i) the technology of

adaptive presentation that supports the provision of various alternative forms of feedback and feedback components, and (ii) the stepwise presentation of the feedback components in the dialogue-based form of feedback. Specific learner's characteristics, which are maintained in learner model and recorded either through learner's interaction with the system or defined by the learner explicitly, are used as a source of adaptation. In particular, the learner model keeps information on learner's knowledge level, preferences on different feedback forms and components and interaction behavior (i.e. the times that the learner under consideration has selected specific feedback forms). The learner model may be accessed and modified by the learner at any time during the interaction and is continuously updated in order to keep always the "current state" of the learner.

The presentation of the results derived from the map analysis is differentiated according to learner's preferences and interaction behaviour. Initially, based on learner's preferences, the map analysis results are presented either in text-based or graphical-based form. However, the learner may select to see the results in the alternative form (i.e. graphical- or text-based). The system keeps track of learner's selections, which constitute his/her interaction behaviour and tailors the feedback presentation form to learner's interaction behaviour.

The dialogue-based form of feedback is supported either unsolicited (with respect to the learning outcomes of the concept mapping activity, the teacher defines if the specific form of feedback would be available) or solicited (learner has the possibility to define his/her preference to the specific form of feedback if s/he wishes). Moreover, in the dialogue-based form of feedback, the learner's knowledge level and preferences are used as the main source of adaptation during the provision of feedback components of the 2nd and the 3rd stage of the dialogue. More specifically, in the initiation of the learner model, the learner has the possibility to define if only the knowledge level or the preferences or both will influence the adaptation process. COMPASS incorporates various strategies in order to determine the feedback components that should be presented, depending on the sources of adaptation. For example, in case only the knowledge level is used as a source of adaptation, the following strategies for the provision of the feedback components of the 2nd stage are applied:

- *Strategy A*: aims to tutor learners with low knowledge level by providing them appropriate learning material. To this end, if learner's knowledge level has been evaluated as low/average on the concept mapping activity, then the available tutoring feedback units (TFU) are provided; learner is encouraged to select and study one of the available TFU and then return to his/her map in order to correct the identified error(s).
- *Strategy B*: aims to guide learners with high knowledge level in order to rethink their false belief. To this end, if learner's knowledge level has been evaluated as high on the activity, then reflective questions are provided; the learner is encouraged to spend some time thinking the questions provided and return to his/her map in order to correct the false belief.

3.4 Learner Support and Control

Having as an objective to support learners during the elaboration of the activity, the following feedback components are available for study: (i) the expert map (EM), (the availability of the expert map depends on the concept mapping task and the decision of the teacher according to the learning outcomes of the activity), and (ii) educational material (TFU) for all the concepts represented on expert map and/or the concepts included in the provided list of concepts. Moreover, as it is considered essential to allow learners to play an active role and take control over their own learning in order to meet their needs and preferences, COMPASS gives learners the possibility to (i) personalize the feedback process by accessing and initiating/updating their learner model in terms of the feedback presentation parameters (e.g. feedback form for presenting the results derived from map analysis, preferences on the types of feedback components, preferences on the characteristics that could be used as source of adaptation), and (ii) have control over the feedback presentation process at any time during the interaction with the environment by selecting the preferred form of feedback and by intervening in the stepwise presentation process of the dialogue in order to activate the desired stage and select the desired feedback components. Also, at any stage of the dialogue, learner has the possibility to inactivate the adaptation of the feedback process.

4 Conclusions and Further Research

In this paper, we presented the feedback process of the COMPASS environment. The discriminative characteristics of the feedback process are: (i) the different forms of feedback supported (text-, graphical- and dialogue-based), (ii)

the provision of multiple Informative, Tutoring and Reflective Feedback Components (ITRFC), which serve processes of informing, guiding/tutoring and reflection, (ii) the adoption of reflective feedback components that encourage learners to "stop and think" and give them hints indicating potentially productive directions for reflection, (iii) the different knowledge modules of the tutoring feedback components that support learners with different preferences and aim to cultivate various skills, (iv) the structure of the ITRFC in multiple layers and their stepwise presentation that supports the gradual provision of feedback and enables learners to elaborate on the feedback information and return to their map in order to correct any errors, (v) the adaptivity of the feedback process that interweaves the gradual provision of the ITRFC with the adaptive presentation of alternative forms of feedback and feedback components, accommodating learners' knowledge level, preferences and interaction behavior, and (vi) the learner support and control offered over the feedback process. A preliminary evaluation of the feedback process during its implementation phase (performed on a limited number of subjects and in a simulated environment) revealed that the incorporation of multiple ITRFC and their structuring/presentation enabled the majority of learners in reviewing their maps, reconsidering their beliefs and accomplishing successfully the concept mapping task (Gouli et al., 2004a). However, a comprehensive evaluation study is in progress in order to investigate several issues such as the effectiveness of the feedback process in learning achievement, in supporting processes of guiding/tutoring and reflection, and in accommodating learner's individual differences.

5 References

Cimolino, L., Kay, J., & Miller, A. (2003). Incremental student modelling and reflection by verified concept-mapping. In *Supplementary Proceedings of the AIED2003: Learner Modelling for Reflection Workshop*, 219-227.

Chang, K., Sung, T., & Chen, S-F. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning*, 17(1), 21-33.

Chi, M., de Leeuw, N., Chiu, M-H., & Lavancher, C. (1994). Eliciting self-explanation improves understanding. *Cognitive Science*, 18, 439–477.

Collins, A. (1987). A Sample Dialogue Based on a Theory of Inquiry Teaching. In C. Reigeluth (Eds), *Instructional Theories in Action, Lessons Illustrating Selected Theories and Models.* Hillsdale, NJ: Lawrence Erlbaum Associates, 181-199.

Conlon, T. (2004). "Please argue, I could be wrong": A Reasonable Fallible Analyser for Student Concept Maps. In *Proceedings of ED-MEDIA 2004, World Conference on Educational Multimedia, Hypermedia and Telecommunications*, Volume 2004, Issue 1, 1299-1306.

Gouli. E., Gogoulou, A., Papanikolaou, K., & Grigoriadou, M. (2004a). Designing an Adaptive Feedback Scheme to Support Reflection in Concept Mapping. In *Proceedings of the Adaptive Hypermedia Conference 2004: Workshop on Individual Differences in Adaptive Hypermedia*, (Eindhoven, Netherlands), 126-135.

Gouli. E., Gogoulou, A., Papanikolaou, K., & Grigoriadou, M. (2004b). COMPASS: An adaptive web-based concept map assessment tool. In *Proceedings of the First International Conference on Concept Mapping*, (September 2004, Pamplona, Spain).

Gouli E., Gogoulou A., Papanikolaou K., & Grigoriadou M. (2005). Evaluating Learner's Knowledge level on Concept Mapping Tasks. In *Proceedings of the 5th IEEE International Conference on Advanced Learning Technologies (ICALT 2005)*, 424-428.

Hsieh, I.-L., & O'Neil, H. (2002). Types of feedback in a computer-based collaborative problem-solving group task. *Computers in Human Behavior,* 18, 699-715.

Jonassen, D., & Grabowski, B. (1993). *Handbook of Individual Differences, Learning and Instruction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Mason, B., & Bruning, R. (2001). Providing Feedback in Computer-based Instruction: What the research tells us. Retrieved 2004 from http://dwb.unl.edu/Edit/MB/MasonBruning.html

Mory, E. (1996). Feedback Research. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology*. New York: Simon & Schuster Maxmillan, 919-956.

Ruiz-Primo, M., & Shavelson, R. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching*, 33 (6), 569-600.

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IN THE HEAT OF THE MOMENT . . . STRATEGIES, TACTICS, AND LESSONS LEARNED REGARDING INTERACTIVE KNOWLEDGE MODELING WITH CONCEPT MAPS

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Abstract. The intent of the article is to provide experience-based, basic, practical observations regarding expert knowledge elicitation with concept maps. This article contains a description of techniques for the interactive, collaborative construction of concept maps by a domain expert and a facilitator (who is typically not a domain expert) and the selection or creation of accompanying resources. After a brief review of relevant literature, this article provides a description of the value of and approaches to advance preparations for concept mapping sessions, strategies and tactics that help sessions to get off to a good start, the process of creating hierarchical organizations of concept maps, making decisions regarding what to capture in concept maps and what to capture by accompanying resources, and the refinement and verification of knowledge models.

1 Introduction

Concept maps have proven useful for the elicitation and representation of expert knowledge. Knowledge elicitation methods using concept maps encompass a range that includes use of pencil and paper or electronic concept mapping tools, interactive approaches, and those in which maps are created off-line from inputs obtained by other means. In some instances, experts create their own concept maps. More often, one or more facilitators who are skilled at knowledge elicitation (KE) but not necessarily expert in the knowledge domain help one or more experts create the concept maps. Interactive, facilitated methods have become the norm at the Florida Institute for Human and Machine Cognition (IHMC). Such sessions are frequently extremely fast-paced, and some basic rules of thumb might improve the results.

The rest of this paper presents a description of some of the lessons the author has learned in 16 years of concept mapping for KE. Following a brief literature review, this article identifies issues pertaining to preparation for the sessions, concerns that arise in the initial sessions such as how to avoid eliciting superficial, well-known knowledge, ways to generate and use focus questions, how to use parking lots, sub-maps and placeholder maps, when to stop mapping and use other electronic resources, what to do when the elicitors seem to be missing a lot of the proceedings, and a few examples of alternative representations to concept maps that might be more suited to the capture of particular types of knowledge. The paper concludes with a summary of the points made. The next section provides a brief overview of literature pertaining to knowledge elicitation and modeling with Concept maps.

2 Knowledge Elicitation and Modeling using Concept Maps

The following brief literature summary provides background for this article. Since Novak and Gowin (1984) originally defined Concept Mapping as a means to externalize science student understandings and misapprehensions, Concept Mapping has proven useful for knowledge elicitation (KE) and knowledge modeling (Ford, et al., 1991; Ford, Cañas, & Coffey, 1993). This early literature on the subject described a concept map as a "mediating representation," an explicit knowledge representation that serves as an intermediary between an expert and a knowledge elicitor in efforts to externalize conceptual knowledge and create meanings. The elicited Concept Maps have been used to structure what have been termed "knowledge models," hierarchically structured groups of concept maps that are linked together and augmented with other electronic media.

Hoffman, Shadbolt, Burton, and Klein (1995) described various types of KE methods including what they termed "contrived" techniques. This category includes the creation of diagrammatic representations of knowledge in the form of linked networks of concepts or Concept Maps. Hoffman et al characterized concept map creation as a contrived technique because elicitation of concept maps does not entail the expert actually performing tasks from his or her usual repertoire of capabilities. The fact that concept mapping is a contrived technique suggests that

augmenting concept maps with other appropriate media to foster greater understanding, a process called knowledge modeling at IHMC, might bear special consideration.

McNeese and colleagues (McNeese et al. 1993; McNeese et al. 1995) were early adopters of concept mapping techniques to create external representations of knowledge that is being communicated. Studies they cited involved the elicitation of maps with a variety of experts including pilots and design teams. More recent work (Brewer & McNeese, 2004) has involved knowledge elicitation with concept maps in service of elucidating emergency response task structures, and the types of information and activities involved in emergency response work. Their newest work addresses strategies to introduce a temporal dimension into the knowledge elicited in order to capture what the authors characterize as "episodic events and temporal patterns."

Novak (1998) described knowledge elicitation as a means of idea generation in groups of people. Novak described working with large groups of people who were sub-divided into smaller groups that built maps, and then re-convened in the larger group to share results. Dumestre (2004) described interactive concept mapping in service of job-task analysis in the Navy. Sessions involved large groups of experts (17 in one group, 18 in the other) with a single moderator and recorder in each group. Dumestre concluded that it was more time efficient to gain group consensus with interactive concept mapping than with traditional note-taking and summarizing.

Concept Maps have been used in institutional memory preservation work. In work at NASA Glenn Research Center (Coffey, 1999), Concept Maps were used in order to capture, represent, and preserve institutional memory of senior scientists on issues pertaining to launch vehicle systems integration. The Centaur upper stage and the RL-10 engine were chosen for detailed analysis in this study. Coffey & Hoffman (2002) described a knowledge elicitation cycle involving an initial preparation phase with an iterative process of determining scope, eliciting, rendering and verifying. The result of the effort was a knowledge model organized around Concept Maps. Coffey, Eskridge, and Sanchez (2004) described interactive concept map creation as a knowledge elicitation scheme for memory preservation work at a nuclear power plant. In this work, the idea of activity maps emerged. Activity maps are useful for the elicitation and representation of the types of activities an expert engages in, and have proven valuable in gaining insight in what experts actually do. That study also demonstrated that it is possible when working with experts to produce at least one rich concept map per hour over an extended period of time (a week or more).

The literature described in this review illustrates a range of methods and goals for which interactive concept map-based knowledge elicitation might be employed. The goal of such work might be to foster idea generation or group consensus pertaining to a domain of knowledge, or it might be to capture uniquely held, idiosyncratic knowledge of an expert. Overlapping but occasionally divergent concerns pertain to the pursuit of these and other goals for concept map-based knowledge elicitation. The remainder of this paper will attempt to enumerate generally applicable principles pertaining to all types of knowledge elicitation with concept maps.

3 Preparing for the Sessions

Experience has shown that if the knowledge elicitors are not domain experts, every bit of advance preparation that is possible makes a positive contribution to the outcome of the work. This is particularly so in sessions aimed at eliciting knowledge from individual experts. It has become just as evident that no two preparations for knowledge elicitation sessions unfold in the same manner or achieve the same results. One of the main benefits of significant advance preparation is the possibility of quickly getting past the foundational knowledge in the domain and into a depth of understanding that might be of use to other experts. The remainder of this section addresses these points.

3.1 You cannot know too much going in

There are two compelling reasons why a knowledge elicitor must know absolutely as much as possible about the knowledge domain under consideration before starting:

- A fundamental issue in successful knowledge elicitation is establishing credibility with the expert. One of the best ways to do this initially is to be conversant in the basic issues the expert deals with.
- Basic efficiency is a separate concern. Experts typically live with significant time pressure. It is unacceptable to attempt to learn the basics of the knowledge domain on the expert's time.

The preparation phase may take on different forms depending on the knowledge domain, the availability and format of background materials, etc. The last several projects in which the author has been involved have addressed ascent guidance for the space shuttle, differential thermo-structural loads and stresses that impact assembly or reconfiguration of the international space station, and the operation of the turbine system in a nuclear power plant. Preparation for the first two of these undertakings was made from papers written by the experts. Since the papers were seminal in the respective fields and described the experts' core work, it was possible to attain a relatively clear understanding of what would be discussed in the sessions and the basic vernacular of the knowledge domain as the experts used it.

Preparing for work with the turbine engineer was completely different. He was a line worker who kept machines running and did not write papers about his techniques as a matter of course. The employing organization had established a program to preserve institutional memory, of which this work was a part. Part of this program was an initiative to collect information regarding what each of the plant's employees knew and did, and the criticality of their work to the overall operation. The summaries were brief, high-level, and in some cases contained errors. Nevertheless, a list of questions that was generated regarding terms used in the summaries, and additional information such as the number and types of people who worked for the expert, yielded some useful background. This information was noticeably different in quality and quantity from resources used to prepare for the other two previously cited activities.

Another element of preparation that can be highly effective is to build one or more concept maps or a complete rudimentary knowledge model of the introductory materials as part of preparation. This model can be reviewed with the expert early in the process to determine accuracy and to fix mistakes, to identify focus questions (which are described in the next section), and to establish rapport. Additionally, showing and reviewing such a knowledge model helps the expert to understand what will be produced by the sessions. Experts are humans and therefore generally not displeased to find that the elicitor is studying their work. In these circumstances, the mapping process plays the same role as it did in Novak's original conception - it allows the expert and the elicitor to identify very quickly any incorrect notions the elicitor constructed as part of the preparation process. Additionally, as described in the next section, such efforts facilitate starting work with the expert at a greater depth than might otherwise be possible.

3.2 Avoiding "knowledge domain 101"

For efficiency, it is important to start elicitation at significantly greater depth than the basics of the knowledge domain. With careful advance preparation specifically geared to the expert's areas of expertise, it is possible to create at least a sketchy overview of what the expert knows before actual knowledge elicitation begins. This is the best possible situation because it can lead to a dialog in which an assessment can be made regarding areas that are generally well documented or known, (and hence, of less interest) and those that might be uniquely or idiosyncratically understood by the expert.

Examination of the concept maps created as part of the preparation process can be a highly useful factor in formulating an initial set of focus questions. By their very nature, these questions should be significantly more focused than a very general approach that starts with "tell me what you know about X." Novak (1998) describes a case in which concept mapping was used to formulate research questions for a doctoral dissertation by building and examining a concept map of the knowledge domain. A total of 6 research questions were identified by posing questions regarding what the possible relationships might be between concepts that were not linked together, but that were thought to have some connection. A similar approach applied to concept maps that were developed as part of the preparation phase could yield an initial group of deep, meaningful focus questions that might be refined before sessions start, or as a first activity with the expert when actual work commences.

4 The Initial Rounds of Knowledge Elicitation

This section addresses issues that arise when getting started. The personnel who manage the project can be expected to inform the expert regarding the goals of the work. However, the expert must be helped to understand what will transpire in the sessions and why the process is carried out as it is. A briefing regarding the goals of the work, accompanied with a review of preliminary concept maps, can help the expert to gain this understanding. This section

describes other concerns including how to use focus questions, bottom-up versus top-down initial efforts, getting an early focus on the emerging concept map, and some heuristics regarding structuring of the model into more detailed concept maps.

4.1 Using focus questions

It is critically important to start with a best-guess focus question to define the goal of the initial session. It might be possible to identify a number of focus questions before sessions start. However, it must be recognized that the initial set of questions might not encompass the range of items of interest that emerge in the sessions. It is also not uncommon for the proceedings to drift off the initial question - an element of opportunism and exploration are always present in the early part of such work. As the session unfolds and more concepts are elicited, a judgment must be made if a different topic is emerging or if the current direction leads to a better articulation of the original focus question with a different emphasis. The session might lead to a modification of the focus question or the identification of a different topic to be explored later. It is a common practice to make placeholder maps - concept maps that hold a question or a few concepts of interest for future consideration.

4.2 Parking lots to Start

It is practically always a good idea to start by writing down a number of concepts and making only minimal efforts to link them together initially. It is easy to arrange them into clusters on the page if such groupings are evident. On the other hand, with a very rapid-pace expert, a great many concepts might accumulate very quickly. If this happens, it is quite likely that some of the concepts may be at a different level of detail (described as granularity) than others, and some may not be relevant to the current topic. Some of the items that are less closely related might be placed in another concept map with a focus question pertaining to the new map. This type of activity is in the general realm of creating sub-maps or placeholder maps, the topic of the next section. Novak's heuristic of approximately 10-12 concepts in a parking lot is reasonable for on-the-fly knowledge elicitation, although rapid-fire sessions can quickly lead to the identification of many more than this. It is necessary to work on linking items together sooner or later, and carrying out the linking process is a good time to get attention focused on the map itself. By referring the expert to the map and explicitly asking for the relationship between two concepts, the focus can be placed on the mediating representation, the topic of the next section.

4.3 Get the focus on the Concept Map

The generally accepted method of knowledge elicitation advocated by the IHMC is a two-person team with one member designated as the moderator and the second member the recorder (Coffey et al. 2003). The role of the moderator is to interact with the expert to keep the conversation moving and on-topic, and to ensure that the recorder is keeping up with the discourse. The recorder actually creates the concept map as the discussion unfolds. The recorder's job is complex; it is not akin to that of a court stenographer since the recorder has to make ongoing decisions regarding the arrangement of items in the map, potential connections between items, when to create sub-maps (see the next section), etc.

Extensive experience with interactive mapping has shown that it is very easy (at least initially) to fall into a process in which the moderator and expert talk back and forth, generally ignoring the emerging representation of the conversation that the recorder is producing, as the recorder struggles to keep up with the flow of ideas. Without a concerted effort to avoid this problem, it is easy for the expert and moderator to lose track of how the recorder is keeping up and, in such situations, important knowledge might be lost. This problem can be avoided by quickly establishing a focus on the concept map. The sooner the focus of the conversation is directed to the construction of a concept map, the better the process works. It takes a conscious effort on the part of both the moderator and recorder to get the attention focused on the concept map. It is also quite possible that discussions can lapse back away from the map even after attention has been directed there for some time.

An alternative to the two-person moderator/recorder approach to knowledge elicitation is the use of a single elicitor who both interviews the expert and produces the concept map at the same time. One of the benefits of this approach is that since the elicitor's attention is directed toward the concept map, it is quite natural to have the expert's attention focused there as well. Although there are many benefits to having two elicitors, this approach affords a natural, easy way to get the session focused on creation of the concept map.

4.4 Creating Sub-maps including Placeholder Maps

Rapid-fire sessions can lead to the accumulation of a great many concepts in a surprisingly short period of time. When it appears that a large amount of detail is being generated in a map, it might become necessary to remove some of the detail, place it in what will be a lower level map, and link to it from the current map. Typically, one node is left in the more general map, and that particular concept is repeated with all the accompanying detail in the sub-map. An important issue with regard to the creation of sub-maps is the maintenance of some consistency in the level of detail that is removed, and the level of detail that remains. If topics are of similar granularity, it is poor structuring to have numerous details pertaining to one of the concepts remaining in the more general map while removing all the details of the other concept to a sub-map. The breakpoint between what is acceptable in this regard and what is not is a judgment, and accordingly, this is a guideline rather than a hard-and-fast rule.

As stated before, some experts methodically expand around a well-focused idea, but ones who do are rare. More often, experts, who tend to see most things somehow connected to most other things, meander around and it is the responsibility of a knowledge elicitor(s) to keep the focus on the topic at hand. If it is realized that an item seems to be related to the topic, potentially of interest, but outside the actual scope of the current map, it is useful to create a placeholder map, possibly with a focus question, for later sessions. The agenda for knowledge elicitation sessions is often quite fluid and takes form as the process unfolds.

There is an element of opportunism in the process whereby it is not usually possible to know in more than broad terms exactly what is best to elicit before-hand. The use of placeholder maps, some of which might be discarded later, is a good means to keep track of potentially interesting issues. An example from the turbine expert was that in discussing a loosely related issue, it was uncovered that he had unique methods of measuring very large things extremely precisely. He had to be able to measure 30 foot-long turbines down to microns and he had his techniques. Knowledge elicitation is usually with experts who have accumulated a lifetime of experience and it is difficult to know what is most important about what they know. Placeholder maps help to articulate possible areas that might be of interest. They can be prioritized by the KE team in terms of which might be the most profitable to explore because knowledge in that area is unique or poorly-documented.

5 “I missed that”

One of the most difficult aspects of managing an interactive knowledge elicitation session is not missing important ideas. This is not a universal problem since some true experts talk slowly, are very measured about staying on-topic, and methodically address a given topic as a concept map is constructed. Others, however, are very rapid-fire in their thoughts and words, putting out many ideas on potentially many subjects, and making it a struggle to keep up.

The single most effective way to avoid this problem and to settle into a productive session in which all the big ideas are captured, is to get the attention of the expert focused on the emerging concept map itself as a mediating representation among the participants. The expert gets visual cues on how quickly and accurately the ideas are being recorded, and this arrangement acts as a natural brake to keep the expert from going too quickly. Another aspect of handling this problem is that the elicitor should always feel free to ask the expert to slow down, repeat, rephrase, etc. It is typically the case that one does not wish to interrupt the thought processes of the expert, but to do so is clearly preferable than to miss important information. It has been shown (Hoffman, Coffey, & Ford, 2000) that interactive knowledge elicitation is an efficient process. For example, efficiencies are not gained by recording and transcribing sessions as an alternative to concept mapping. Accordingly, it is not a bad thing to slow down a bit.

A related issue to the problem of missing information is the fact that many experts tend to digress, ramble, or otherwise move off the subject. If it becomes evident that the expert is predisposed to do this, the knowledge elicitor should try to record the ideas, stop the expert, enlist his/her aid in making a judgment regarding whether the ideas are of sufficient importance to make a placeholder map, produce the placeholder as appropriate, and then get back on the topic. This is another example of the balance that must be struck between allowing the expert sufficient latitude to explore related ideas while keeping on subject and not missing important but not immediately relevant issues.

One last area of difficulty in adequately documenting knowledge on the fly pertains to illustrative stories or anecdotes. It is difficult to create concept maps interactively that contain all the richness and detail that is contained

in stories that illustrate a point an expert is trying to make. Instead of trying to keep up in such a circumstance, it might be better to plan to capture the story as video or in some other format. This approach is relevant to the idea of using the right tool for the job, the topic of the next section.

6 The Right Tool for the Job

Concept maps are good for the representation of conceptual knowledge and the interconnections among concepts in the domain. Tergan (2005) states that a benefit of having a structuring tool such as CmapTools (http://cmap.ihmc.us, CmapTools 2003; Cañas et al, 2004) is that content knowledge and information that augments and explains the concepts in a concept map greatly enhances the utility of the representation. It is clear that concept maps are not the ideal representation for all forms of knowledge. While various broad characterizations of knowledge are possible, Basque and Leonard (2004) used a form of concept mapping to distinguish among concepts, principles, procedures and facts. While each of these types of knowledge might appear as a node in a map, details pertaining to that type of knowledge might not. Concept maps are different than procedures or process flow charts, although one can construct a flow chart with typical concept mapping software. Facts are more suggestive of information than knowledge, and might be optimally represented in a list. The same might be said for Principles. Accordingly, it seems evident that different elements that might arise in interactive concept mapping sessions might be expressed in a variety of representations. This section will discuss some general guidelines for using the best representation.

6.1 When to stop mapping and start resourcing

The judgment of when to stop mapping and start using other accompanying resources is not simple to make. If known resources exist that elaborate an issue under consideration, they will, of course, be considered for use. Often, however, such resources are not identified until after some mapping has occurred. Additionally, as mentioned previously, some forms of knowledge are not easily rendered in a concept map. Illustrative examples may or may not be stored in concept maps. Stories captured on video are another example of items that might be better represented in other means than in concept maps.

Other examples of knowledge that is not best rendered in a concept map have been identified. For instance, derivations in a series of math equations with numbered equations and explanatory text is likely the best way to represent this type of knowledge. Comparing a number of items according to a number of characteristics readily lends itself to a matrix organization. Attempting to represent such information in a concept map will inevitably lead to a tangled map that is both difficult to compose and difficult to understand. A multi-dimensional comparison of two items is a special case of this idea and still better represented as a table. While representation of data in tables or equations might be the best form for an application, summarizations of the major conclusions that might be drawn from the data or the rationale for the equations might be captured in a concept map.

Another aspect that helps with the decision regarding when to stop mapping and start resourcing is the goal of the knowledge model. Briggs et al. (2004) point out that a knowledge model created at the NASA Center for Mars Exploration (CMEX) entitled "Return to Mars," was mainly meant to organize a large group of extant pictures and other resources pertaining to Mars. By comparison, the STORM knowledge model, also briefly mentioned in that paper, was built to capture deep expert knowledge pertaining to regional effects on weather forecasting. Although the CMEX knowledge model contained more concept maps than the STORM model, the narrower focus of the STORM model meant that its concept maps went into greater detail on individual topics.

The STORM model included many additional resources including videos of experts describing ideas that were deemed more comprehensible in video format. Additionally, Klein's Critical Decision Method (Klein et al. 200x), which is a detailed narrative on a timeline, proved useful for the representation of decision-making processes that unfold over time. Such representations are complementary to concept maps in the sense that they might capture highly detailed, focused knowledge that can be organized with concept maps.

The issue of how to identify accompanying resources must also be considered. It is to be expected that experts will refer to documentation as a routine matter during knowledge elicitation. In the course of mapping sessions, elicitors can note items to which the expert refers and record where they should go in a knowledge model. On the other hand, identification of resources can be treated as a separate, deliberate step. It is to be expected that some

knowledge domains will naturally have more resources available than others. For example, The CMEX work was meant to organize other resources from NASA's large collection.

6.2 Capturing Processes

One might initially capture process knowledge in a concept map. One of the most appealing aspects of capturing process knowledge is that conceptual knowledge pertaining to the rationale for the process might appear in the same map. A process map might start with an elicitation of the concepts pertaining to the process, some of which might be steps in the process and others not. As the map becomes well-populated, the steps in the process are identified and ordered. A feature of CmapTools called the "nested node" has proven useful for the representation of process information. The process name might appear with the nested node closed, and details of the process are viewed by opening it. On the other hand, tools that can help the user walk through processes represented as complicated decision trees might provide a more useful representation of a process than a concept map. In such circumstances, an initial round of concept mapping might be a good vehicle for the development of rules that ultimately reside in software to manage the decision tree.

7 Refining and verifying concept maps

Concept mapping is best viewed as an iterative process. After an initial round of mapping, it is always beneficial to revisit concept maps that have been created. Experts are typically able to identify multiple issues regarding representations that do not capture the precise meanings intended. Omissions are readily identified. Refinement of the wording of concept maps, particularly with regard to the linking phrases, is a critical part of the process. This is typically a more relaxed phase since the activity entails refinement of knowledge that is already there rather than frenetically attempting to capture it in the first place as it flies by.

Since some offline effort to refine concept maps between or at the end of a wave of sessions, to link them together, and to populate them with resources, occurs without the benefit of the expert, the possibility always exists that errors might be introduced into the concept maps or lower quality or inappropriate resources might be linked. It is helpful to refine maps on the evening on which they were elicited and are still fresh in the elicitor's mind. It is extremely important not to change the sense of what is in the map. The changes should be reviewed with the expert or experts the next day, particularly if more than trivial changes are made.

It should be noted that an additional aspect of this phase is that gaining a focus on the concept map itself is not a problem as it can be in the early phases of the work. The refinement phase is typically undertaken with the expert from whom the concept maps were elicited. It is a task of stepping through concept maps methodically and examining nodes, linking phrases, and links to other maps and resources. Even after protracted sessions, experts typically are able to identify changes to be made. This activity might be viewed as different from a verification phase that is performed with a different expert.

Some evidence exists (Hoffman, Ford, & Coffey, 2002) that the changes made by a different expert than the one from whom the concept map was originally elicited are relatively minor; perhaps on the order of 10% of the concepts and linking phrases might be changed. However, it is to be expected that if concept maps on the same knowledge domain are elicited from two experts, they might be quite different. Whether such differences are a consequence of different areas of interest within a domain, different use of vernacular, or differing constructions of truth is an open question.

8 Summary

This work seeks to enumerate very basic, practical guidelines and principles regarding interactive elicitation of concept maps and knowledge models for knowledge elicitation and preservation. After reviewing literature on knowledge elicitation with concept maps, the paper examines several issues. For instance, it is always important for elicitors who are not experts in the knowledge domain to prepare as best they can before sessions start. It is easy to lapse into the elicitation of very basic, generic knowledge from the expert's standpoint without sufficient advance preparation. One strategy that can mediate against eliciting superficial knowledge is the creation of a basic

knowledge model as part of the preparation phase. The overview of the knowledge domain facilitates making decisions regarding where to start with the expert.

As the sessions get underway, decisions regarding when to create sub-maps and placeholder maps are made. The idea of maintaining consistent granularity in a concept map when making sub-maps is addressed. The useful idea of creating placeholder maps when the discussion strays from the topic at hand is also described. The issue of when to stop mapping and start using other resources is addressed. This issue is difficult and involves judgments of the best representation to convey an item of interest. Several examples of alternative resource types are presented and described. The article closes with a discussion of how to verify knowledge models both as the emerging models are refined in nightly cycles that can be reviewed with the expert the next day, and with a different expert who is brought in to verify independently. Like all knowledge elicitation methods, knowledge modeling as defined at IHMC still has elements of art and craft in it, but an awareness of issues and strategies that have been uncovered over the years can produce more efficient and effective work.

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9 References

Basque, J., Imbeault, C., Pudelko, B., Lionard, M. (2004). Collaborative knowledge modeling between experts and novices: A strategy to support transfer of expertise in an organization. In: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 75-82). Pamplona, Spain: Universidad Pública de Navarra.

Brewer, I., & McNeese, M. (2004). Expanding concept mapping to address spatio-temporal dimensionality. In: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 101-107). Pamplona, Spain: Universidad Pública de Navarra.

Briggs, G., Shamma, D. A., Cañas, A. J., Carff, R., Scargle, J., & Novak, J. D. (2004). Concept Maps Applied to Mars Exploration Public Outreach. In A. J. Cañas, J. D. Novak & F. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 109-116). Pamplona, Spain: Universidad Pública de Navarra.

CmapTools (2003). IHMC Concept map software, A knowledge construction toolkit. [Online] Retrieved 6/19/2006. http://cmap.ihmc.us/

Cañas, A. J., Coffey, J. W., Reichherzer, T., Hill, G., Suri, N., Carff, R., Mitrovich, T., & Eberle, D. (1998). El-Tech: A performance support system with embedded training for electronics technicians. Proceedings of the Eleventh Florida AI Research Symposium (FLAIRS '98), 79-83. Sanibel Island, FL.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W., & Hoffman, R. R. (2002). A knowledge modeling approach to institutional memory preservation. The Journal of Knowledge Management, 7(3), 38-49.

Coffey, J. W. (1999). Institutional memory preservation at NASA Glenn Research Center. Technical Report, NASA Glenn Research Center, Cleveland, OH.

Coffey, J. W., Eskridge, T. C., & Sanchez, D. P., (2004). A Case Study in Knowledge Elicitation for Institutional Memory Preservation using Concept Maps. In: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 151-158). Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W., Cañas, A. J., Novak, J. D., Hoffman, R. R., Carnot, M. J., & Jost, A. (2003). Facilitating the creation of graphical knowledge representations for brainstorming and decision support. Proceedings of the 7th World MultiConference on Systemics, Cybernetics and Informatics. (SCI2003), Orlando, FL. 198-202.

Dumestre, J. (2004). Using CmapTools software to assist in job task analysis. In: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 227-235). Pamplona, Spain: Universidad Pública de Navarra.

Ford, K. M., Cañas, A. J., Jones, J., Stahl, H., Novak, J., & Adams-Webber, J. (1991). ICONKAT: An integrated constructivist knowledge acquisition tool. Knowledge Acquisition, 3, 215-236.

Ford, K.M., Cañas, A.J., & Coffey, J.W. (1993). Participatory Explanation. Proceedings of the Sixth Florida AI Research Symposium (FLAIRS '93), Ft. Lauderdale, FL, April, 1993.

Ford, K. M., & Bradshaw, J.M. (1995), Beyond the Repertory Grid: New approaches to Constructivist knowledge acquisition tool development, International Journal of Intelligent Systems, 8, 287-333.

Hoffman, R. R., Coffey, J. W., & Ford, K. M. (2000). A case study in the research paradigm of Human-Centered Computing: Local expertise in weather forecasting. Technical Report, Institute for Human and Machine Cognition, Pensacola FL.

Hoffman, R. R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995), Eliciting knowledge from experts: A methodological analysis, Organizational Behavior and Human Decision Processes, 62, 129-158.

Klein, G. A., Calderwood, R., & MacGregor, D. (1989). Critical Decision Method for Eliciting Knowledge. IEEE Transactions on Systems, Man, and Cybernetics, 19: 462-472.

McNeese, M., Zaff, B., Brown, C., Citera, M. & Selvaraj, J. (1993). Understanding the context of multidisciplinary design: Establishing ecological validity in the study of design problem solving, Proceedings of the 37th Annual Meeting of the Human Factors Society, Santa Monica, CA.

McNeese, M., Zaff, B. S., Citera, M., Brown, C. E., & Whitaker, R. (1995). AKADAM: Eliciting user knowledge to support participatory ergonomics. International Journal of Industrial Ergonomics, 15, 345-363.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept Maps as facilitative tools in schools and corporations. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Tergan, Tergan S-O. (2005). Digital Concept Maps for Managing Knowledge and Information. In: Tergan S, Keller T (Eds). Knowledge and information visualization: Searching for Synergies. LNCS 3426. Heidelberg, Germany: Springer. 185-204.

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INNOVATIVELY DEVELOPING A TEACHING SEQUENCE USING CONCEPT MAPS

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Abstract. A student teacher's work with concept maps illustrates the conceptual structure underpinning a teaching sequence in order to communicate efficiently his perceptions of what it means to developmentally and conceptually teach a selected topic in contrast to simply compiling a sequential list of sub-topics. Main insights from the case study were that constructing concept maps prompted the student teacher to reflect deeply about his own knowledge of mathematics beyond the assignment topic and challenged him to strategically organize the results of this thinking and conceptual analysis into visual, hierarchical displays of concept networks to parsimoniously and meaningfully illustrate the relationships between key and subsidiary concepts of the assignment topic.

1 Introduction

Whilst syllabus outcomes and key ideas are useful to guide the planning of teaching sequences, "they are only 'frameworks' – teachers need in-depth knowledge of mathematical concepts and processes so as to enrich them" (Bobis, Mulligan & Lowrie, 2004, p. 25). With the prevailing curricular emphasis on encouraging students to think mathematically (New South Wales Board of Studies (NSW BOS), 2002)), there is a need to conduct research into innovative ways of supporting mathematical thinking and reasoning in deeper and more conceptually based ways. Hence, the main study explored ways in which growth in understanding mathematical concepts and processes could be supported through concept mapping and vee diagramming by investigating secondary student teachers' use of concept maps and vee diagrams (i) to critically analyse selected content of the *7-12 Mathematics Syllabus* (NSW BOS, 2002), (ii) to illustrate their conceptual understanding of syllabus outcomes and indicators, activities and problems; and (iii) to develop requisite skills in the design of conceptually rich activities to promote working and communicating mathematically. The study was guided by Ausubel's theory of meaningful learning which proposes that learners' cognitive structures are hierarchically organized with more general, superordinate concepts subsuming less general and more specific concepts (Ausubel, 2000; Novak, 2004). By constructing concept maps and vee diagrams (maps/diagrams), students illustrate publicly their interpretation and understanding of a topic/problem in terms of interconnections between concepts, principles and methods. Recent research (Afamasaga-Fuata'i, 2005, 2004a, 2004b) with Samoan undergraduate mathematics students demonstrated the usefulness of maps/diagrams as valuable meta-cognitive tools to scaffold students' thinking and reasoning, to illustrate students' developmental and conceptual understanding, and to enhance efficiency in communicating mathematically as they learnt new mathematics topics or solved mathematics problems in their university mathematics courses. Through participation in social critiques over the semester, students received constructive feedback to further improve individually constructed maps/diagrams; subsequently their end-of-study maps of assigned topics were structurally more complex and differentiated than initial maps as a result of thinking about thinking, interactions with others and concept mapping. Whilst these studies (Afamasaga-Fuata'i, 2005, 2004a, 2004b) focused on undergraduate students' applications of maps/diagrams as learning, the main study that is partially reported here with student teachers at an Australian regional university focused on the applications of maps/diagrams as pedagogical tools. The following sections briefly describe the study's methodology before presenting data from one student teacher's work in developing a teaching sequence through concept mapping. Discussion of the student teacher's concept map data and some insights based on the case study are also provided.

2 Methodology & Data Collected

The main study's methodology was a design experiment in which student teachers critically analysed syllabus outcomes, problems and activities (i.e. *critical analysis*) for underlying concepts and principles (i.e. *conceptual structure*) before illustrating the results on maps/diagrams followed by an examination of (a) the kinds of *discourse* that emerged during *critiques* of presented maps/diagrams and *student reflections* on how their constructing experiences impacted on the way they planned, thought and viewed the teaching of mathematics topics; (b) the types of participation norms (i.e. *socio-mathematical norms*) established for the development and critique of maps/diagrams during weekly workshops; and (c) the types of *practical means* by which the researcher "orchestrated relations among these elements" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 9). The

sample included ten internal students of the two secondary mathematics education units who agreed to participate. The lecturer-researcher introduced and used maps/diagrams in her presentations of materials during weekly workshops. Regular assignments, in parts, required students to prepare unit plans and lesson plans for various content areas of the *NSW 7-12 Mathematics Syllabus*. The study was in two parts. Firstly, as learners, students constructed maps/diagrams as tools to illustrate and communicate their conceptual and methodological understanding of the mathematics content in activities/problems. Secondly, as student teachers preparing for teaching practicum, they developed lesson plans and activities using maps/diagrams to guide instruction. Data collected included maps/diagrams presented in workshops and final maps/diagrams included in regular assignments, student reflections, and researcher's field notes. This paper presents the case study of one student teacher's work (Robert Brennan) on using concept maps to plan a teaching sequence on the topic "Derivatives." Specifically, student teachers were required in Assignment 1, to prepare a teaching sequence on the topic "Derivatives" based on the syllabus notes: *Section 8. The Tangent and the Derivative of a Function* for the *Higher School Certificate (HSC) Mathematics 2/3 Unit -Years 11-12* (NSW BOS, 2002, pg. 50-53). The next sections describe Robert's teaching sequence concept maps.

3 Data Analysis

3.1 Learning to Concept Map

The key characteristics of concept maps, namely the (i) hierarchical organization of key and subsidiary concepts and (ii) inclusion of linking words on connecting lines to form propositions from chains of "node $\xrightarrow{\text{linking words}}$ node" triads, were illustrated and demonstrated through a number of pre-prepared concept maps. During group/individual work in weekly workshops, student teachers practiced concept mapping selected topics/problems/activities and concerns were addressed as they emerged during these activities. For Robert, he identified, selected and ranked key and subsidiary concepts of the selected topic/problem/activity before organising them hierarchically from most general to more specific concepts. While constructing a hierarchy of nodes, reflecting upon the emerging network of interconnections, selecting linking words, critically evaluating and assessing the map's overall validity in terms of the discipline knowledge, Robert inevitably realized that he was thinking more deeply and intensively about possible variations of underlying conceptual structures and cognitively deliberating between alternatives. Not surprisingly, Robert called this preparatory stage "*the verb-type*" by which he meant "*the act of doing the map"* and is *"represented by a pseudo-algorithm to draw the concept map – such as choosing key concepts and possible links.*" Explaining his experiences, he said: "*There are in fact 2 'knowledge constructs' gained from doing concept maps. Firstly the 'verb-type', by which I mean the act of doing the map, even if it ends up in the bin at the end. And secondly, the 'noun-type' by which I mean the end product, the actual map of the conceptual structure*." It seems that whilst learning to concept map, Robert realized for himself that "*there are actually 2 types of maps … there is the pre-existing one that is embedded in the mapper's brain, and then there is the map that actually best describes the (unit/problem/activity) for the mapper*." Basically conjecturing that these "2 *maps and their differences could be described by Vygotsky's zone of proximal development*," he explained that, "*I was confused as to whether I was mapping my 'prior knowledge construct map' or the 'map of best description' and so I struggled with the concept maps.*" These distinctions (or confusions) between the likely nature and focus of maps were perceived and defined by Robert as "*dimensions*" of a concept map; see Table 1 for his schematic representations of dimensions.

	*Prior-Knowledge Construct Map	#Best Description Map
Verb-type Knowledge Construction	(1) Represented by pseudo-algorithm to draw concept map – such as choosing key concepts & possible links.	(2) Represented by a plan to re-arrange the prior-knowledge construct map to best solve current problem.
Noun-type Knowledge Construction	(2) Final copy of concept map that accurately represents "what is in mapper's head."	(3) Final copy of concept map, which may represent a solution to a mathematics problem or a teacher's unit/lesson plan.

* Already existing and may be primitive or erudite but exists and must be discovered.
\# Varies depending on the nature of the problem; i.e., is it a mathematics problem to be solved; or a content summary of a topic of study by a teacher?

Table 1: Student's Perceptions of "Dimensions" of a Concept Map

Elaborating further, Robert proposed yet another dimension namely the "*focus*" of the map. He wrote: "*By this term I mean the 'qualitative nature' of the map – Is it concrete in nature so that it's usefulness lies in teaching a student to solve a particular mathematics problem; or is it descriptive in nature providing an abstract summary of a topic?*" However, sharing and discussing these reflections later on in-class clarified further for Robert the need to explicate the intended purpose and specific focus of a map, often a common point of confusion when learning to concept map for the first time. That is, explicating the purpose and focus of map first ensures the appropriate selection of concepts, hierarchical organization and suitable linking of relevant nodes to enhance the map's overall cohesiveness and meaningfulness. For example, a concept map of a mathematics problem (Type 1) illustrates the conceptual structure embodied by the problem and underpinning its solution whilst a topic concept map (Type 2) illustrates the conceptual and epistemological structure of the key ideas (i.e. mathematics concepts and principles) relevant to the topic. As a consequence of such qualitative distinctions, Type 1 map would be more contextualized and situated in contrast to the more general overview and abstract Type 2 ones.

Apparently from Robert's reflections (in *italics* above) and schematic representations in Table 1, preparing and constructing a concept map demanded much deliberation and decision-making, cognitive and analytical processing beyond the mere recall of formal definitions and general formulas. As a result, by the time the first assignment was due, Robert had become increasingly more proficient in selecting key and subsidiary concepts with strengthened skills in hierarchically organizing concepts into cohesive groups and more confident in constructing viable networks of propositional links to communicate his understanding of the task's conceptual structure. Explaining this growth in understanding, Robert wrote: "*I realized that these 2 types of maps ['prior knowledge construct map' and 'map of best description'], need to be well-defined before mapping begins*". Through his 2-dimensional schema in Table 1, Robert posed two viable pathways for the construction of a '*best description map*.' Firstly, by progressing vertically down the 'prior-knowledge construct map' (Column 1 of Table 1) from (1) a pseudo-algorithm through (2) a final copy of what is in the mapper's head and then horizontally across to (3) a final copy representing a solution to a mathematics problem or teacher's unit/lesson plan. Secondly, by progressing horizontally along the 'verb-type knowledge construction' (Row 1 of Table 1) from (1) a pseudo-algorithm on to (2) a plan to re-arrange the prior-knowledge construct map and down to (3) a final copy of concept map to represent a solution to a mathematics problem or teacher's unit/lesson plan. The choice of pathways appears dependent on whether the focus is a problem or a unit/lesson. Irrespective of the pathway taken, each seems to represent a progressive or developmental trajectory from an initial preliminary version to a finalized '*best description map*.' Presented below is Robert's final 'best description' maps obtained through the first pathway for the purpose of illustrating a teaching sequence.

3.2 Overview Concept Maps - Mathematics 2/3 Unit-Years 11-12

Instead of designing a teaching sequence directly from syllabus notes, Robert Brennan first of all, situated the topic of "Derivatives" amongst those required for Years 11-12 in the *Mathematics 2/3 Unit* (corresponding to the HSC Mathematics and Mathematics Extension 1 courses, NSW BOS (2002)) to provide a better overview of topics to be taught prior to introducing "Derivatives." Proceeding by identifying the main ideas from syllabus notes, Robert went beyond the requirements of the assignment and constructed 14 overview concept maps (only *two* shown here), which covered a range of Years 11-12 prescribed topics. He commented that: "*For me it seems that I must firstly define the entire space of the (unit) before attempting to define the (unit) itself.*" Shown in Figures 1 and 2 are Robert's first two overview concept maps illustrating some of his organisational hierarchies to depict differentiating levels of generality (Level #) from the most general concepts to progressively more specific concepts towards the bottom of map. For example, Figure 1 is an overview of Year 11 Mathematics (Level 1) that is subsumed under 3 main concepts namely "(A) Building Blocks of Functions", "(B) Real Functions", and "(C) Examples of Functions" at Level 2, with the order A, B, and C indicating a preferred teaching sequence. Relevant to the topic "Derivatives" is the middle branch subsumed under the Level 2 node: "B. Real Functions" with a triple-branching link connecting to 3 less general concepts (at Level 3) namely "I. Foundations", "II. The Slope Problem" and "III. Introduction: Product, Quotient & Chain Rule". Again, the ordering I, II, and III suggests that (I) is the required prior knowledge to the topic "Derivatives" embodied by the middle "II. The Slope Problem" sub-branch (marked *). Similarly, the adjacent "(A) Building Blocks of Functions" branch on the left and the adjacent "(C) Examples of Functions" branch to the right, could be likewise read from top to bottom.

In comparison to Figure 1, Figure 2 on Year 12 Mathematics (Level 1) shows the relevant information in relation to the topic: "Derivatives" such as nodes subsumed under the Level 4 nodes: "HSC (2 Unit) Mathematics

topics/units" and "HSC (3 Unit) Mathematics Extension I topics/units" namely "II. Calculus" (marked *) and "I. Applications of Calculus to the Physical World" (marked **). Reading from top-to-bottom, the relevant proposition P1 is: "HSC (2 Unit) Mathematics topics/units *comprises 3 "sub"-strands:* I. Coordinate Geometry, II. Calculus and III. Transcendental Functions *and one unit:* 1. Kinematics".

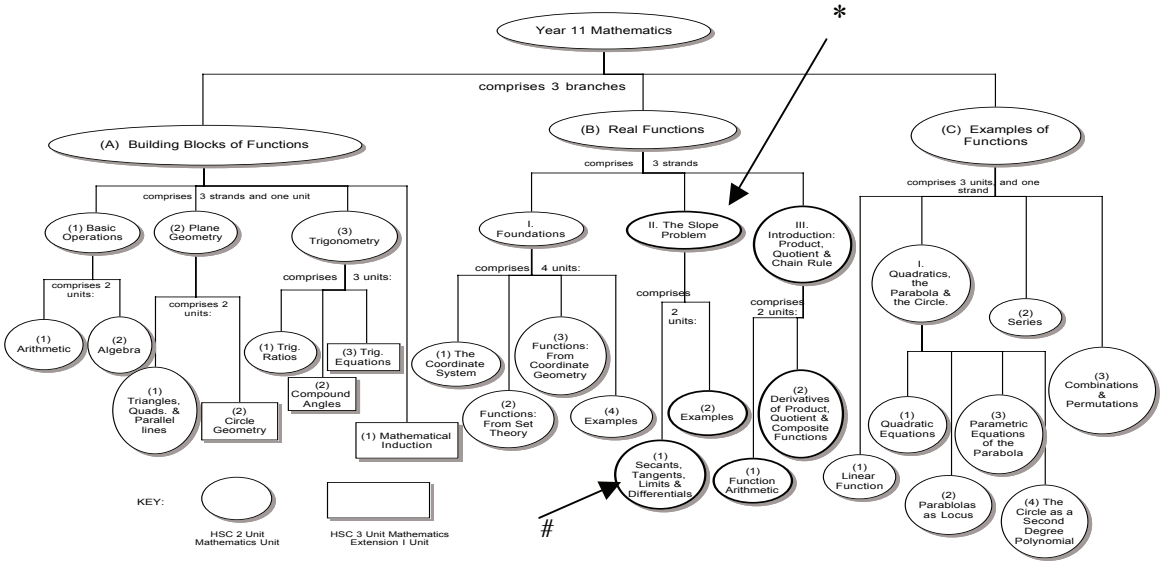


Figure 1. Year 11 overview concept map.

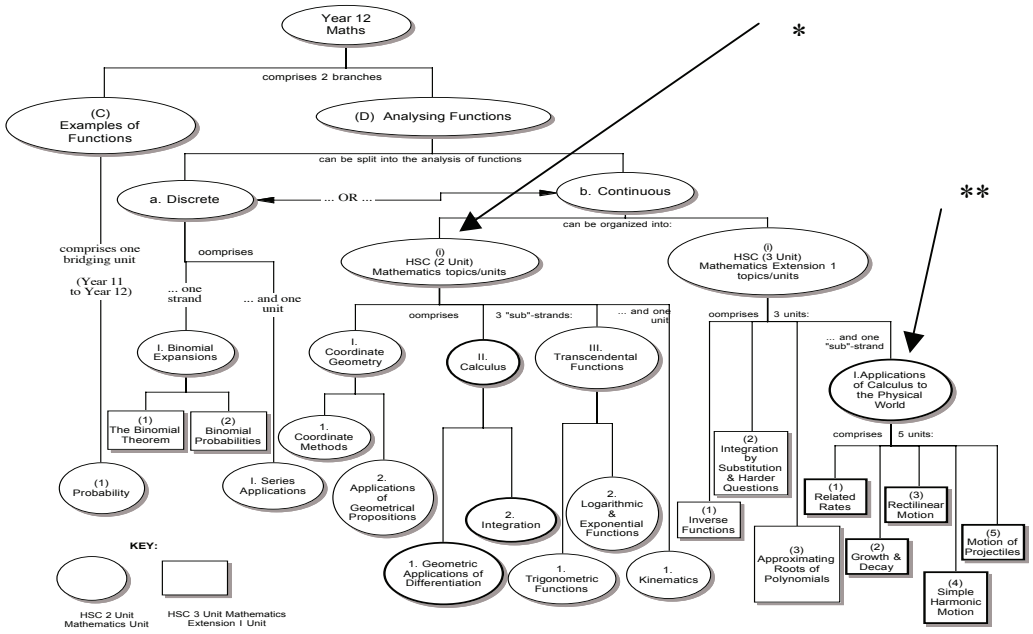


Figure 2. Year 12 overview concept map.

From the "II. Calculus" node is a progressive differentiation double-link to connect to the two terminal nodes "1. Geometric Applications of Differentiation" and "2. Integration" but with no linking words. Situated within the other calculus-related sub-branch (marked **) subsumed under the node: "HSC (3 Unit) Mathematics Extension I topics/units" is the proposition (P2): "1. Applications of Calculus to the Physical World *comprises 5 units:* (1) Related Rates, (2) Growth & Decay, (3) Rectilinear Motion, (4) Simple Harmonic Motion, and (5) Motion of Projectiles". In fact, Figure 2 clearly depicts the nested structure of HSC 2 Unit Mathematics topics within HSC 3 Unit Mathematics and showing that HSC 3 Unit extends topics initially encountered in HSC 2 Unit Mathematics. This inter-relationship is schematically shown by the left-to-right order of the Level 6 concept hierarchies in Figure

2. Collectively reading from the two maps, Figure 1's middle branch, from left to right illustrates the syllabus' expectation and Robert's plan that the topic "Derivatives" would be introduced via "II. The Slope Problem" (marked *) through secants, tangents, limits and differentials (marked #). In comparison, Figure 2 provides a more general overview of this sequencing of topics but situated within Year 12 HSC 2 Unit Mathematics (i.e. "1. Coordinate Geometry" to be covered prior to "II. Calculus") and including clear distinctions of topics covered as applications of calculus to the real world within HSC (3 Unit) Mathematics (marked **). Following on from this general overview of Years 11-12 Mathematics courses, Robert developed a detailed concept map to illustrate a more developmental approach to "Derivatives" which explicitly builds upon students' prior knowledge of gradients of linear graphs by elaborating further the meaning of the terminal node: "Secants, Limits, Tangents & Derivatives" of Figure 1 (marked #). This process is briefly described next.

3.3 Teaching Sequence Concept Map – Topic "Derivatives"

Robert's critical and conceptual analysis of *Section 8: The Tangent and the Derivative of a Function* (NSW BOS, 2002, pg. 50-53) yielded 19 main groups of sub-topics of which 5 was identified to be the most relevant for introducing derivatives; see Figure 3 for the 5 syllabus referenced sub-topics.

Section 8.3 Gradient of a secant to the curve y = f(x).
Section 8.4a Tangent as the limiting position of a secant.
Section 8.4b The gradient of the tangent.
Section 8.5a Formal definition of the gradient of y = f(x) at the point where x = c.
Section 8.6a The gradient or derivative as a function.

Figure 3. List of sub-topics relevant to "Derivatives" (NSW BOS, 2002).

These sub-topics in Figure 3 eventually formed the basis of Robert's topic concept map for the introduction of derivatives shown in Figure 4. Selecting the node: "Secants, Limits, Tangents and Derivatives" (from Figure 1, marked #) as the titular node at Level 1 of Figure 4, the next hierarchical level showed progressive differentiating triple-links to three main concepts: "(1) The 2-Point Method", "(2) The Limiting Process" and "(3) Derivative Functions" at Level 2. Furthermore, the resulting 3 branches and concept hierarchies appeared organized around the three types of knowledge namely (i) prior knowledge, (ii) new knowledge (i.e. derivatives) and (iii) extensions, reflective of the philosophy of preparing learning activities promoted by the mathematics education unit Robert was enrolled in. Specifically, the leftmost branch indicated the prior knowledge ("(1) The 2-Point Method" branch) described in the syllabus students require before being introduced to the derivative concept. Emanating from the "(1) The 2-Point Method" node is a split-link that generated propositions: (P3): "(1) The 2-Point Method *for finding the gradient of* a) straight line*s*" and (P4): "The 2-Point Method *for finding the gradient of* b) Secants (8.3)" where 8.3 was a reference to syllabus notes, Section 8.3 (NSW BOS, 2002, pg. 50) and the first of the 5 sub-topics listed in Figure 3. From the middle Level 2 node: "(2) The Limiting Process" are two progressive differentiating split-links to Level 3 nodes: "Geographically" and "Algebraically" which form the extended proposition P5: "(2) The Limiting Process *which can be looked at* Geographically *by introducing* the 3 types of points *which are* Fixed: P(c, f(c)), Moveable: Q(u, f(u)), and General R(x, f(x))". Emanating from the "Moveable: Q(u, f(u))" node is a split-link that form propositions P6: "Moveable: Q(u, f(u)) *can generate tangent at point P(c, f(c)) by:* a) Moving Q to P (8.4a)" and P7: "Moveable: Q(u, f(u)) *can generate tangent for any point on curve R(x, f(x)) by:* b) Moving Q to R (8.4a)". On the other hand at the Level 3 node: "Algebraically" of the middle branch, are two differentiating links which formulated an extended proposition P8: "The Limiting Process *which can be looked at* Algebraically *by noting the change of* x: $\Delta x=c-u$ and *by noting the change of* y: $\Delta y=f(c)-f(u)$". The subsequent merging of cross-links (i.e., integrative reconciliation) from the two Level 4 nodes "$\Delta x=c-u$" and "$\Delta y=f(c)-f(u)$" formulated proposition P9: "$\Delta x=c-u$, $\Delta y=f(c)-f(u)$ *which yields* $m=\frac{\Delta y}{\Delta x}$" with a single link to the Level 6 node to form the extended proposition P10: "$m=\frac{\Delta y}{\Delta x}$ *and the language for moving Q to P is*: $\lim_{u \to c}\left(\frac{f(c)-f(u)}{c-u}\right)$ *which gives:* The gradient of the tangent at x = c. (8.4b) *which is:* a) Denoted f'(*c*), and called the differential coefficient of f(x) at c. (8.5a)" The middle branch evidently focuses on the geometric introduction of a tangent and the algebraic representation of the limiting gradient as a differential coefficient. In contrast to the middle branch, the rightmost branch depicts the progressive development (or extension) of the concept "differential coefficient f'(c)" (marked *) to the more general concept "Derivative Functions" (Level 2). Specifically, the first proposition (P11) is: "(3) Derivative Functions *are best studied by introducing the identity*: $u=x+\Delta x$" followed by the triple-pronged proposition (P12) "$u=x+\Delta x$ *which yields:* $f(u)=f(x+\Delta x)$, $u-x=\Delta x$, $u \to x \equiv \Delta x \to 0$" (Level 4). Cross links from the latter nodes merged to form the

proposition P13: "f(u)=f(x+Δx), u–x=Δx, u→x ≡ Δx→0 *which upon substitution give* $\lim_{u \to x} \frac{f(u)-f(x)}{u-x} = \lim_{\Delta x \to 0} \frac{f(x+\Delta x)-f(x)}{\Delta x}$ " *which is:* "a) Denoted f'(x), and called the derivative function of f(x). (8.6a)."

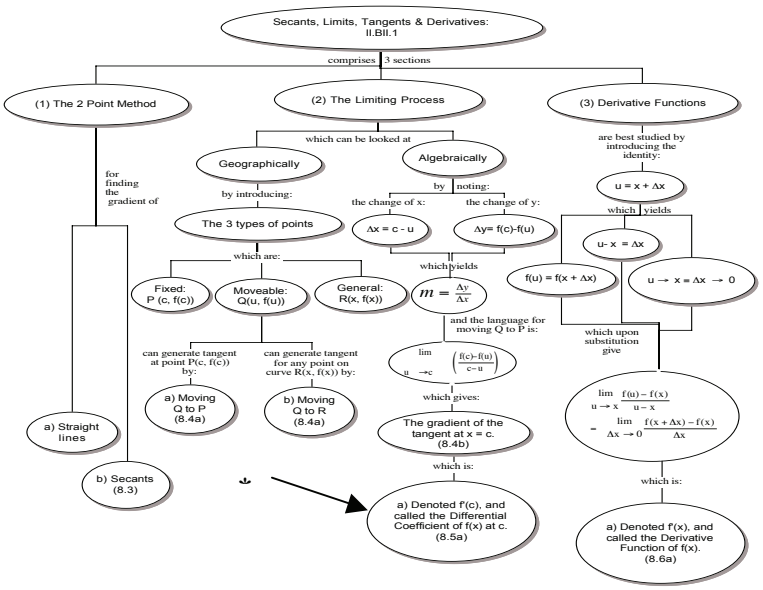


Figure 4. Topic "Formal definition of derivatives" concept map

Overall, Figure 4 shows a topic concept map with an explicit organization into 3 main branches, which implicitly suggests a teaching sequence from left to right. Furthermore, within each concept hierarchy, there is a logical development of ideas implied by reading from the top to the bottom levels and from left-to-right. Similarly, when reading from the terminal node of a (sub-)branch up to the top level of the adjacent concept hierarchy to the right as described above. The advantage of the visual and more informative display of the interconnectedness of key ideas with respect to each sub-topic (i.e. 8.4a, 8.4b and 8.5a) is clearly depicted by comparing each of the three sub-branches subsumed under the "(2) The Limiting Process" middle branch to the linear sequential list in Figure 3. Of additional interest is the explicit connections between concept maps such as the link between the titular node: "Secants, Limits, Tangents and Derivatives" of Figure 4 and the same-named node in Figure 1 (marked #). Taken together, Figures 1, 2 and 4 clearly illustrate a visual trend from the macro view of main topics in a 2-year mathematics curriculum (Figures 1 and 2) to a micro-view of key and subsidiary concepts within a sub-topic (Figure 4); that is, there is an apparent increasingly more detailed elaboration of conceptual interconnections most relevant to "Derivatives" when moving from Figures 2, 1 to 4.

4 Discussion

The discussion of findings are organized around four main points namely (1) concept maps of critical and conceptual analysis, (2) workshop discourse, (3) socio-mathematical norms, and (4) practical management of the learning ecology within weekly workshops. Each issue is briefly discussed next.

Concept Maps of Critical Analysis - Robert's overview concept maps in Figures 1 and 2 provided a big picture view of the Years 11 and 12 topics within which the topic "Derivatives" is situated. Each map represented what Robert had categorized as "*final copy*" of a concept map to accurately represent a teacher's unit plan. The visual positioning of concepts within hierarchies and the overall grouping of relevant hierarchies, not only suggested potential teaching sequences when the map is read from left-to-right, but it also depicted the level of generality of ideas and/or concepts when read from top-to-bottom. Together, they defined a unique position for a node/hierarchy, roughly paralleling that of a point on the Cartesian plane, whilst simultaneously denoting a relative position amongst a network of nodes/hierarchies highlighting the interrelatedness of ideas. Findings demonstrated that concept maps provided a parsimonious, visual organization of interconnecting ideas, not only at the macro-level (Figures 1 and 2),

but also at a relatively more in-depth micro-level of a teaching sequence (Figure 4), which collectively enriched the design of a teaching sequence. The cognitive processes of identifying key and subsidiary concepts, hierarchically organising them, constructing and finalising concept maps necessarily required that the student teacher reflected deeply upon his own knowledge of mathematical concepts and processes whilst determining the most viable, visual hierarchical organizations of interconnections he anticipated would promote his future students' conceptual understanding of derivatives. Labelling the preparatory version his "*verb-type*" or "*prior knowledge*" map, he proposed that this was a necessary step before finalizing a "*noun-type*" or "*map of best descriptions*." His reflective practice when mapping subsequently led him to develop a two-dimensional schema of "*verb-type→noun-type*" by "*prior-knowledge→best-description*" to illustrate qualitative differences between types of maps. Although cognitive demands on the student teacher to critically analyse syllabus documentation, whether or not a concept map is used prior to developing a teaching sequence would probably be very similar, the significant difference however, is in the extra cognitive and meta-cognitive skills to meaningfully and visually organise ideas into hierarchies of propositional links to display and highlight the "interconnectedness" of concepts across different levels of generality and specificity. Hierarchically organizing concepts evidently challenged Robert to clarify his thinking as he sought out mathematical principles to provide underlying frameworks that enhance the cohesiveness and meaningfulness of nested hierarchies (branch). This cognitive exercise appeared to demand reflective, lateral and deeper thinking about mathematics concepts and processes in order to construct visual and schematic representations of meaningful and cohesive knowledge systems (e.g. Figures 1, 2, and 4) in contrast to a sequential and linear view of topics from reading notes (e.g. Figures 3).

Workshop Discourse - The kinds of discourse that emerged during critiques of presented maps in workshops involved interactions and exchanges of ideas between the student teacher presenting his/her own map and his/her peers and lecturer-researcher responding and making critical comments usually in the form of requests for clarifications, recommendations for additions/deletions, or confirmations of presented information. Consequently over the semester, Robert learnt to interact and respond appropriately to critical comments as he argued the correctness of his maps, provided counter-arguments to points raised by his peers, or sought modifications of maps when justifiable. Through these social negotiations, argument and debate, the student teacher demonstrated growing awareness of the importance of adjusting the level of his mathematical language (manifested as concept labels and linking words) to be consistent with the recommended level of the syllabus' staged outcomes. Furthermore, students voluntarily shared their reflections of their experiences simultaneously encouraging others to do the same. Ensuing discussions therefore, focussed on how their mapping experiences impacted on the way they planned, thought and viewed the development of teaching sequences/learning activities. For example, Robert discussed initial difficulties as he learnt to concept map problems/activities/units such as the difficulty of identifying appropriate and concise labels for main ideas, clarifying the purpose and focus of maps, and determining the most suitable hierarchies. However, through workshop discourse, Robert's concerns were eventually clarified. Through the discussion of his reflections, he demonstrated an in-depth engagement and reflective practice with the task of concept mapping which previously and independently prompted him to schematise the mapping process as "*dimensions*" to qualitatively clarify the purpose and focus of concept maps.

Socio-mathematical norms - The types of participation norms established in workshops included participation in group/class analysis of key and subsidiary ideas in topics/problems/activities; the transformation of analysis results into concept maps leading to group/class co-construction of exemplar maps; class critiques of individually constructed maps; and discussions of student reflections and mapping experiences. Finally, established socio-mathematical norms influenced, modulated and directed the dynamics of group/class discussions and critiques in weekly workshops. Undoubtedly, these norms impacted the way Robert planned and developed his final 'best description maps' of a teaching sequence as presented here.

Practical Management of the Learning Ecology - The types of practical means by which the lecturer-researcher "orchestrated relations among [the different] elements" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 9) included selecting appropriate tasks (activities/problems/topics) to introduce concept mapping, providing support to students whilst they were learning for the first time, critiquing their work and setting more tasks to challenge their critical abilities and skills not only of concept mapping but including critical analysis of syllabus outcomes. The lecturer-researcher also facilitated group discussions and critiques during map presentations, and coordinated the sharing of students' reflections as materials for discussion of the impact of concept mapping on their own 'thinking about learning' and 'thinking about teaching.' With workshop presentations and reflection sessions focussing on concept maps, ensuing discourse brainstormed multiple ways in which classroom activities could be supported and

facilitated through having their future students present and communicate their mathematical understanding via concept maps. Whilst the actual involvement of school students in concept mapping was not part of the main study, using concept maps by student teachers as pedagogical tools was.

5 Main Insights

With the acquired expertise and proficiency in constructing concept maps, the student teacher was empowered to use these tools innovatively (i) to critically analyse syllabus outcomes, and (ii) to design a suitable teaching sequence by hierarchically and visually clarifying prior knowledge and future knowledge and using appropriate mathematical language to effectively communicate staged-appropriate mathematics content. Since completed, practice and final maps encapsulated both the conceptual and epistemological frameworks of a topic, through their construction, the student teacher routinely searched for connections between key and subsidiary concepts, and whilst doing so, he made insightful observations about the qualitative distinction between the nature of maps, depending on their purpose and focus, in terms of a two-dimensional schema, to distinguish between maps that are more abstract as in topic concept maps or those that are more concrete as in problem concept maps. For example, he also distinguished between dimensions of a concept map when used as a metacognitive tool to collect his thoughts and ideas about the focus of the map (verb-type) and a final concept map described as his 'best-description map (noun-type). A significant advantage of being proficient in concept mapping is the acquisition of critical skills that can be usefully applied to many situations such as demonstrated through his additional effort to situate the assigned topic within the macro picture of the two-year mathematics curriculum.

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7 References

Afamasaga-Fuata'i, K., (2005). Students' conceptual understanding and critical thinking? A case for concept maps and vee diagrams in mathematics problem solving. In M. Coupland, J, Anderson & T. Spencer (eds). *Making Mathematics Vital.* Proceedings of the Twentieth Biennial Conference of the Australian Association of Mathematics Teachers (AAMT), (pp. 43-52). January 17 – 21, 2005. University of Technology, Sydney, Australia.

Afamasaga-Fuata'i, K. (2004a). Concept maps and vee diagrams as tools for learning new mathematics topics. In A. J. Canãs, J. D. Novak & Gonázales (eds). *Concept Maps: Theory, Methodology, Technology*. Proceedings of the First International Conference on Concept Mapping September 14-17, 2004 (pp. 13 – 20). Dirección de Publicaciones de la Universidad Pública de Navarra, Spain.

Afamasaga-Fuata'i, K. (2004b). An undergraduate's understanding of differential equations through concept maps and vee diagrams. In A. J. Canãs, J. D. Novak & Gonázales (eds). *Concept Maps: Theory, Methodology, Technology*. Proceedings of the First International Conference on Concept Mapping September 14-17, 2004 (pp. 21 – 29). Dirección de Publicaciones de la Universidad Pública de Navarra, Spain.

Ausubel, D. P. (2000). *The Acquisition and Retention of Knowledge: A Cognitive View*. Dordrecht; Boston: Kluwer Academic Publishers.

Bobis, J., Mulligan, J., & Lowrie, T. (2004). *Mathematics for Children. Challenging children to think mathematically.* Pearson Prentice Hill, Australia.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32(1):9-13.

New South Wales Board of Studies (NSW BOS). (2002). Mathematics K-6 Syllabus 2002.

Novak, J. D. (2004). A science education research program that led to the development of the concept mapping tool and new model for education. In A. J. Canãs, J. D. Novak & Gonázales (eds). *Concept Maps: Theory, Methodology, Technology*. Proceedings of the First International Conference on Concept Mapping September 14-17, 2004 (pp. 457 – 467). Dirección de Publicaciones de la Universidad Pública de Navarra, Spain.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

INTEGRATING A CONCEPT MAPPING TOOL INTO A VIRTUAL LEARNING ENVIRONMENT: PEDAGOGICAL AND TECHNOLOGICAL CHALLENGES

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Abstract. Interoperability and integration of digital concept mapping tools has not been widely prioritized and supported by software developers. Digital alternatives to paper-based concept mapping (from simple digital whiteboard to dedicated concept mapping software) are increasingly popular among educators, but computer-based concept maps are still difficult to analyze, assess, expand or export to other software platforms. Lack of interoperability and poor integration of concept mapping tools with widely used Learning Management Systems increases workload of teachers, because of poor reusability and automation opportunities.
This paper describes conceptual design and implementation of a concept mapping tool that has been integrated into an open-source virtual learning environment IVA. Despite this concept mapping tool has several unique pedagogical features, interoperability with other stand-alone concept mapping tools has been reached. For instance, concept maps can be exported from IVA to CmapTools or other tools that support XTM specification.

1 Introduction

We are living in the age of learning technology boom: new software systems and tools are appearing too fast to be properly implemented into everyday practices in educational institutions. Stand-alone desktop educational multimedia applications ceased to be the mainstream way of using ICT in education – nowadays everything has to be Web-based. Having an up-to-date virtual learning environment or, as it is often called, Learning Management System (LMS) seem to be a must for every school and college. Due to rapid development of this kind of systems, significant number of organizations are considering to change their existing LMS to a newer, better or cheaper one (Paulsen 2003). Despite of predictions that soon this boom will be over and one killer app will dominate on the learning technology market (just like it happened with office software in mid-90s), the trends are controversial. On one hand, we have seen the recent merger of largest LMS providers (Blackboard and WebCT), but many of their competitors keep the leading position in smaller countries (Norway, Sweden, Finland, the Netherlands) where e-learning has become a normal part of academic life (Paulsen 2003). In the open-source world, the variety of new LMS's is even increasing. Information portal Edutools.info lists as much as 61 Learning Management Systems, each of these are used in large number of institutions. In this situation, considering the increasing needs for re-usability of digital learning materials and virtual mobility of students, interoperability of e-learning systems and tools becomes a crucial factor. Bartlett et al (2003) define interoperability as *‚the ability to transfer and use information in a uniform and efficient manner across different organizations and information technology systems*'. In the context of Learning Management Systems, interoperability means the ability of two different LMS's (or a LMS and a Learning Object Repository) to easily exchange different kinds of information, for instance:

- the digital learning objects and their metadata (using IEEE LOM specification)
- collections of learning objects (using SCORM specification)
- quizzes and self-tests (using IMS QTI specification)
- calendar events and ToDo's (using vCal)
- learner information profile (using IMS LIP specification).

One of the challenges on the way towards interoperable LMS is related to teachers' needs for specific pedagogical tools/modules that are based on widely used active learning methods like Jigsaw groupwork (Aronson & Patnoe 1997), role-play, Progressive Inquiry (Hakkarainen 2003) etc. For the sake of interoperability, most LMSs try avoid too specific modules, thus decreasing the pedagogical affordances of the system. Concept mapping tool can be seen as one of these specific modules that is requested by the teachers but not yet implemented in an interoperable manner in any LMS.

At this point, we would like to specify our approach to concept mapping. We rely on the works of Novak and Gowin (1984) who have defined concept map as a '*schematic device for representing a set of concept meanings embedded in a framework of propositions*'. Concept maps have been used in education in many ways: either as advance organizer made by a teacher, groupwork method or as an instrument for assessing the learning outcomes of

students. An alternative but quite close technique to concept mapping is mind mapping (Buzan 1991): an image-centered radial diagram where concepts or topics are organized as hierarchical branches. In the context of developing our online concept mapping tool, we see mind maps as a more restricted subset of concept maps.

While paper-based concept mapping is fun, effective and easy to implement, digital tools have their advantages: digital concept maps can be easily archived, copied/multiplied, modified, transported, organized etc. There are various commercial and open-source software packages for working with concept maps. Most of these packages are still not Web-based and prefer the radial and hierarchical approach typical to mind mapping. There are only a few Web-based tools that support concept mapping, the most advanced and well-known of which is IHMC CmapTools (http://cmap.ihmc.us). In the context of Learning Management Systems, concept maps can be drawn using a shared whiteboard tool, which is available in most LMSs. Concept mapping with shared whiteboard has its pros and cons: ease of use and collaboration support are strong points, while reusability and semantics are weak.

This paper provides an overview of the development of an online concept mapping tool that is integrated into a Web-based Learning Management System IVA and is interoperable with other concept mapping software packages that support XTM (XML TopicMaps) as an export-import format for concept maps. First, we are going to demonstrate how poor is the interoperability among current concept mapping tools and how it can be increased with the help of XTM. Then we introduce the pedagogical and technological foundations of IVA LMS and describe the typical scenarios of using the integrated concept mapping tool for individual and group assignments.

2 Interoperability of educational concept mapping software

The dominant approach for describing knowledge structures and associating them with information resources are related to Topic Maps standard. Work on Topic Maps was initiated in the beginning of 1990s by the Davenport Group, in the context of developing the DocBook Data Type Description for interchange of computer documentation. In 2000, Topic Maps were formalized as an ISO International Standard (ISO 13250). Topic map is a semantic network, where different topics are interconnected using associations and instantiated with occurences (information resources related to the topic).

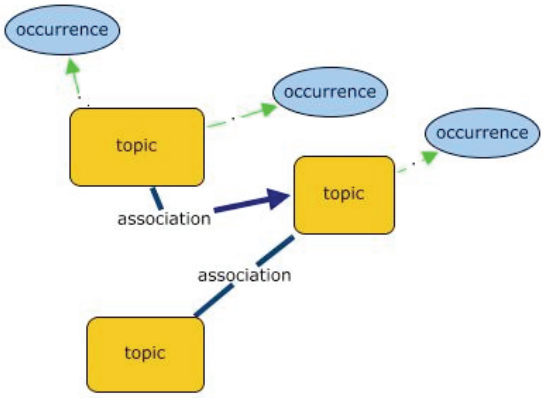


Figure 1. The structure of a Topic Map

Topic maps can be used as a formal description standard for making concept maps interchangeable between different software applications. In this case, the topics represent concepts, the associations represent relations and the occurrences can be interpreted as links to information resources relevant to the associated topic (e.g. external Web pages). In practice, Topic Maps are mostly created using XTM (XML Topic Maps) specification that allows easy interchange of Topic Maps between different Web-based applications.

Of course, XTM is not the only available solution for making concept maps interchangeable: there is also a simplified text-based notation for Topic Maps called Linear Topic Maps (LTM) and an authoring language called AsTMa. Resource Description Framework (RDF) has alternative approach to describing the semantic metadata of

information resources through triples (subject-predicate-object). Despite the fact that RDF and Topic Maps have many things in common, they are not completely compatible and translatable into each other (see Moore 2001). We selected XTM as the format for interchanging concept maps between our concept map tool and other applications mainly because this format is also used by IHMC CmapTools and their repository of re-usable concept maps. Unfortunately, XTM is not yet supported by majority of other concept mapping software providers. We tried to find out empirically, which other formats can be used for interchanging concept maps between the popular concept mapping (and mind mapping) software packages: Mindmanager, OpenMind, SmartIdeas, VisiMap, Inspiration, FreeMind, Cmap and IVA.

Despite the fact that several packages are able to export concept maps as standard text files and popular word processing formats (.txt, .rtf, .doc), the resulting export files have different data structures and they cannot be imported into other software packages. For instance, in some cases an exported MS Word document can include the image of map accompanied with outlined text that demonstrated the hierarchical relations of concepts, while in other cases the MS Word export file contains only outlined text or image file names, which are used to construct the map. In some cases, the exported text file includes outlined text, while in others the text file may be complete with maps, text content and different metadata of levels structure, links, added object information, description etc. This is why VisiMap can not correctly import exported .doc or .rtf files.

	Cmap Tools	**OpenMind**	**Smart Ideas**	**VisiMap**	**Inspiration**	**Mind Manager**	**Freemind**	**IVA**
CmapTools	XTM, outlined txt, proposition	-	-	-	**Outline txt**	-	-	**XTM 1.0**
OpenMind	-	MS Word, PowerPoint MathWare Mediator	-	-	-	-	-	-
SmartIdeas	-	-	Ideas project .ipr	-	**Inspiration .ins**	-	-	-
VisiMap Professional	-	-	**Plain text**	Map .mmp, Plain text, RTF	**Outline txt**	-	-	-
Inspiration	-	-	-	-	Inspiration .ins, Plain text, RTF	-	-	-
Mind-Manager	-	-	-	-	-	MPX, MS Word	-	-
Freemind	-	-	-	-	-	**MPX**	Branch	-
IVA	XTM 1.0	-	-	-	-	-	-	XTM 1.0, CSV

Table 1: Concept map interchange formats between different software applications.

Plain text files exported from SmartIdeas can be imported perfectly and result with a correct map, whereby the Inspiration software opens such plain text files only as text and do not draw a map. CmapTool is able to import text

files with map outline exported from Inspiration, but not always correctly. Table 1 illustrates the poor interoperability of major commercial and open-source concept/mind mapping software packages.

As CmapTools seemed to have the most open approach to concept map interoperability and they also maintain a repository of downloadable concept maps in XTM format, we decided to choose XTM-based export-import for IVA concept mapping tool. Before we introduce the IVA concept mapping tool, the pedagogical foundations and structure of IVA LMS deserve some attention.

3 Pedagogical foundations of IVA LMS

IVA is a Web-based Learning Management System developed at Tallinn University in order to advocate constructivist approaches and practices in e-learning (IVA 2006). IVA is an adaptation of another open-source Zope product called FLE3 (Future Learning Environment 3, see http://fle3.uiah.fi). Just like FLE3, IVA is released under GNU General Public License (GPL) as free and open-source software. Anyone could download the latest version of IVA source code from home page of the IVA development project at http://www.htk.tlu.ee/iva. IVA is developed as a product of a leading open-source Web application server Zope. The development of IVA was supported (among others) by the Ministry of Education and Research of Estonia, Hansapank and the Tiger University Program of The Estonian Information Technology Foundation. IVA is currently available in Estonian, English, Russian and German.

What does the name IVA mean? On one hand it could be read as an acronym (e.g. Interactive Virtual Academy). On another hand, IVA is a metaphor in Estonian language and means ‚a seed' (also ‚point' or ‚meaning'). In 1817, the Reverend Otto Reinhold von Holtz published a series of moralist stories for Estonian peasants under a slogan ‚story is a shell, meaning is a seed'. Since then this hermeneutic slogan has been widely used among teachers and teacher educators in Estonia, when they want to stress the importance of looking deeper below the surface in order to understand better the meaning, or ‚the point' of phenomena. The red dot in IVA logo is symbolizing ‚the point' we are trying to make with our new learning management system: e-learning is not about changing just a shell (or media) of learning delivery. In order to make full use of opportunities offered by new powerful learning environments, both teachers and learners should look deeper behind the routine of traditional educational practices and discover new ways of meaning-making. We hope that our system with its intuitive user interface and innovative pedagogical tools helps them in this endeavor.

As opposed to many commercial Learning Management Systems, IVA is not ‚pedagogically neutral'. The structure and functionalities of IVA system advocate constructivist approaches to learning and teaching (Laanpere et al 2005). For constructivists, learning is not merely transmission of objective knowledge - each learner constructs actively his/her own ‚picture of the world', associating new meanings with previous experiences and communicating with others. According to D.H.Jonassen (1994), the three most important conceptual pillars for designing a truly constructivist learning environment are three C-s:

1. Meaningful and authentic **Context** for learning,
2. Tools, support, time and space for personal knowledge **Construction**
3. Support for **Collaboration** and group reflection and production.

The structure of IVA user interface contains three sections that are directly based on Jonassen's three C-s: there is the shared Bookshelf with learning resources that provide domain-specific context for learning, each learner has his/her own personal Webtop (Web-desktop) for knowledge construction and reflection, and there are various Workshops for collaborative learning. One of the most important features of IVA are various types of individual and group assignments that can be given by a teacher to learners: essays, quizzes, peer reviews, readings, discussions (based on Progressive Inquiry or E. de Bono's Six Thinking Hats templates), role-plays, group projects and more. When a teacher creates an assignment, a dedicated submission folder will be created in the learner's personal portfolio or in the group portfolio (if this is a group task).

While developing a new concept mapping tool, we had to find pedagogically meaningful ways to integrate this tool into existing conceptual framework of IVA. As a result of participatory design sessions with potential users, we decided that concept mapping should be used in IVA for both individual and group assignments on two levels: simple (with limited functionalities) and advanced (with few or no restrictions). Another important feature of the

new tool that was decided to be implemented was dedicated to automating the assessment of concept maps according to the framework provided by Fischler et al. (2001). The next chapter illustrates functionalities of IVA concept mapping tool through descriptive usage scenarios.

4 Scenarios of using the integrated concept mapping tool within IVA LMS

There are two ways to use concept mapping tool within IVA LMS: individual and collaborative. In case of individual use, every learner will build his/her personal map instance from scratch or modify the template prepared by the teacher. In case of the collaborative use, each small sub-group of students will create and edit a sub-version of a concept map template given them by the teacher. Yet, collaborative concept mapping exercise cannot be performed simultaneously – only one user can change the map at the time and other users are able to observe the changes. The next group member will be granted permission to edit the group's concept map after the current user completes the operation (which in most cases happens within a few seconds), or after her/his session expires (after two minutes of idle status).

For each concept mapping assignment, the teacher can specify a set of conditions like the deadline for submission, the default color scheme and other layout properties of concept map, the type of assignment, the level of restriction (either none, restricted or full concept mapping menu can be made available for students).

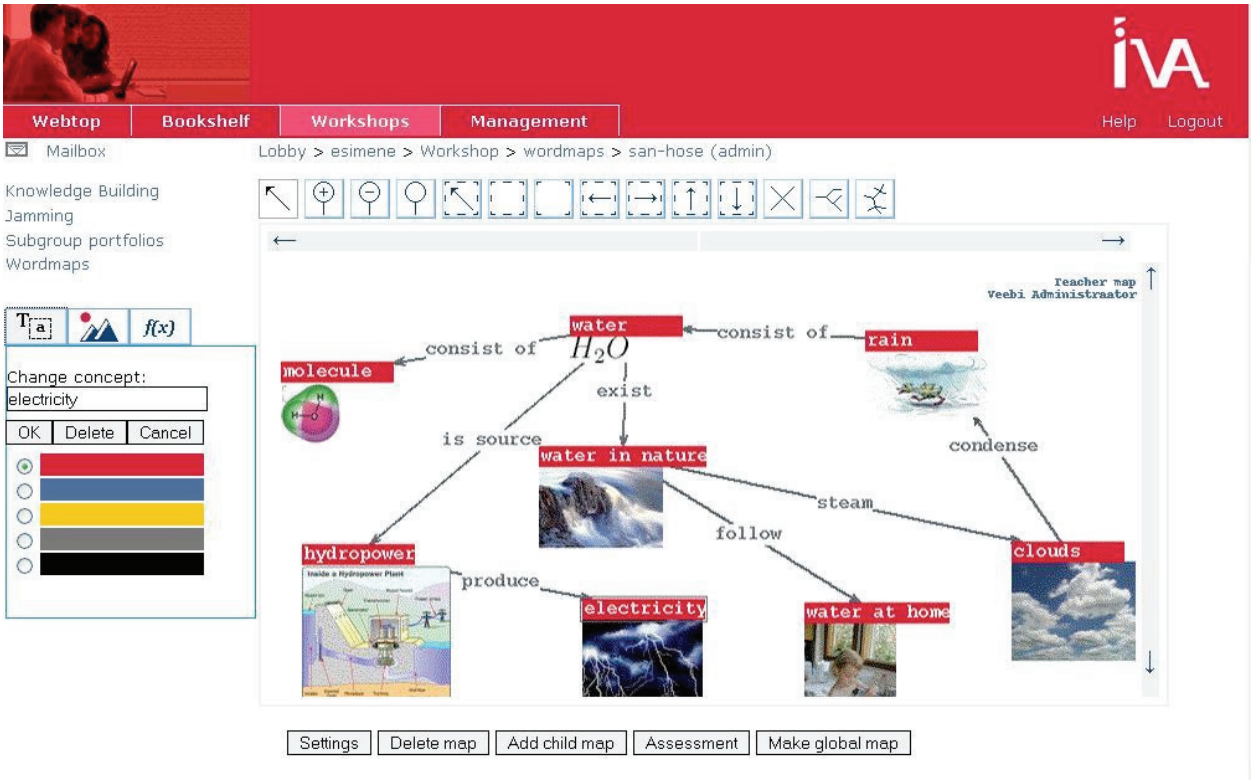


Figure 2. Adding images to a concept map.

Both individual and collaborative concept mapping tasks could have three different assignment types:

- **Allocate and connect** assignment is the simplest version of concept mapping exercise, suitable for younger students, but also for people with poor computer skills or without previous experience of concept mapping. In this case, learners do not see the concept mapping menu at all – the only thing they can do is to rearrange preset concepts and connect any two concepts using preset relation types. If the teacher decides so, learners may be allowed to add new concepts and relation types.

- **Create and design** is a more advanced type of assignment where learners start building a concept map from scratch and are able to manipulate the map to a large extent using concept mapping menu. The default menu type is ‚minimal', but it can be changed by the teacher to ‚extended'. The minimal menu allows to add images, change the color scheme, customize line shapes (thickness, arrowheads). The extended menu allows to work with maps that are larger than the computer screen area. Learners can upload new images needed for their concept map into a common ClipArt folder which is accessible for all participants of this course. Learners can, if needed, replace a concept with an image (see Figure 2 above).
- **Custom type** is defined by the teacher by setting different assignment properties.

4.1 Creating a new concept mapping assignment

While creating a new assignment, teacher goes first to Workshops section and adds a new Teacher's Map. The next step is specifying the properties for the map. For example, younger students would need more simple type task and less functionalities. Here the some of properties that can be edited by teacher:

- **Default color scheme**. Each color can be associated with semantic value.
- **Versioning**. If versioning is allowed, each student can make one or more copies of the Teacher's Map. By default, versioning is allowed. Learners will be able to practice before they design their final concept map.
- **Formula editor**. If formula editor is switched on, a student can add mathematical symbols to a concept map. Mathematical formulae and symbols will be associated either with concepts or relations just like ordinary image files (see Figure 3 below).
- **Access properties**. Students can be granted the right to change the map properties by themselves.
- **Public map**. Sometimes it is important to hide the concept map from other learners (e.g. in order to avoid blind copying from faster learners).
- **Editable map**. By default this property is not checked, then students can only see the Teacher's Map without being able to edit it. But if you want to engage learners in collaborative concept mapping, map should be made editable.
- **Hyperlinks, attachments**. Allowing students to add hyperlinks and file attachments to concepts.
- **Maximum number of concepts**. Teacher may need to limit the quantity of concepts that can be used on the map.
- **Maximum number of relations**. Sometimes it could be important to let the learners decide, which relations are more important than others – then this feature might become handy.
- **Fixed number of relation types**. Students can be permitted to use only limited number of relation types.
- **Fixed set of concepts**. Teacher may list the set of concepts, which are required for concept mapping. Again, concept maps with fixed set of concepts are more easy to compare and evaluate.
- **Fixed set of relation names**. Some concept mapping tasks may require only fixed set of relation types (e.g. Universal Language Modeling task that has relations: part of, context for, instance of, generalization for etc.). Concept maps with fixed set of relations are more easy to compare and evaluate.

After defining the properties for the new Teacher's Map, teacher goes to the Management section which is not accessible by students – otherwise the User Interface of IVA LMS looks the same for teacher and learner. Under the Management section, teacher can add a new concept mapping assignment that uses the Teacher's Map as a starting point. Learners will see the assignment description in their personal Portfolio on their next logon. When a learner clicks on the link ‚Start working on the assignment' in his/her Portfolio, a personal instance of the Teacher's Map will be created for the learner.

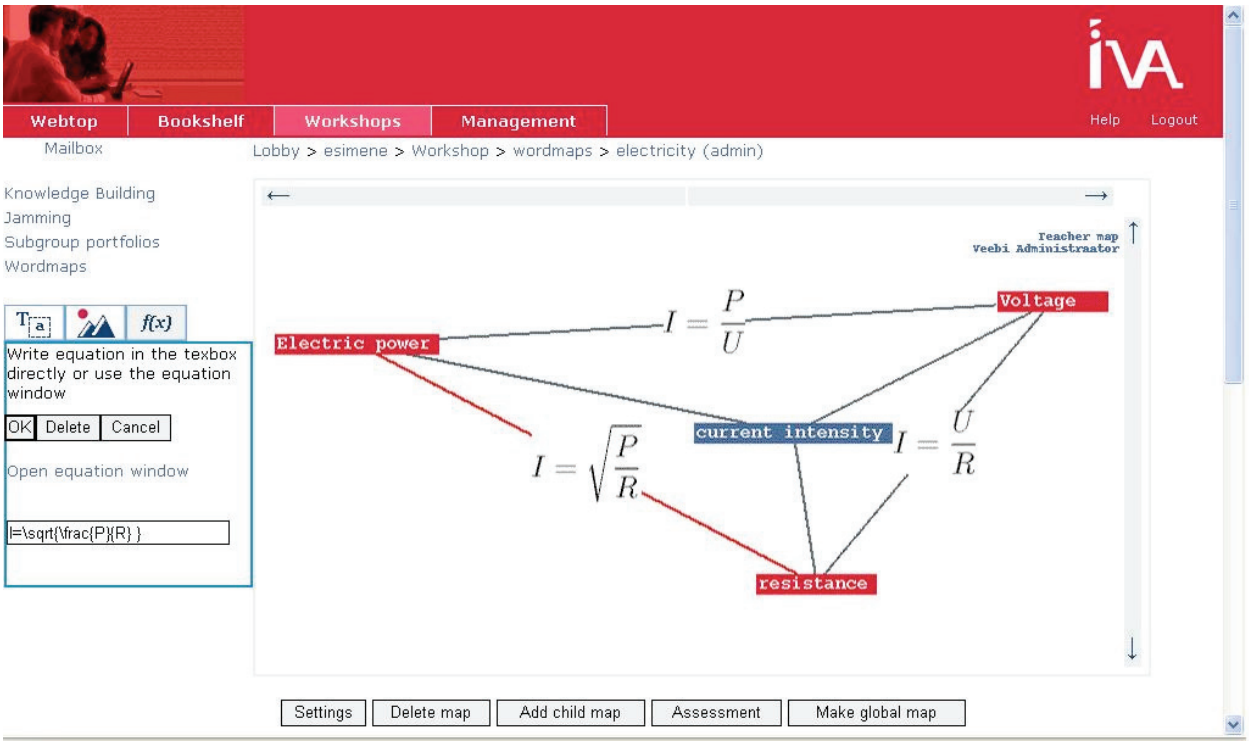


Figure 3. Using the Formula Editor within a concept map.

4.2 Working on a concept map

While designing the concept mapping tool for IVA LMS, we wanted to avoid heavy add-in frameworks like Java that would complicate the installation process of IVA (which is already quite challenging to most of server administrators). As we wanted to provide collaborative concept mapping opportunities (that imply server-side drawing solution), we also decided not to use Flash-based drawing of concept maps. These decisions left us with the native imaging framework for Zope-based products: we used Python Imaging Library (PIL) and JavaScript for drawing the concept maps, thus sacrificing the drag-and-drop feature. Many advanced computer users complain in the beginning when they have to re-learn to use point-and-click instead of drag-and-drop, but in most cases the learners will get used to draw concept maps 'the IVA way' quite quickly. A click on an unoccupied spot within the area of map will create a new concept. If the new concept will not be given a name at once, it will be deleted after the next mouse click. Click on an existing concept selects this concept, after which the user can either to rename, delete or connect it with other concept. The usability testing on users from different age groups showed that this way of drawing the concept maps is intuitive and easy to learn.

4.3 Assessing the concept maps

IVA concept mapping tool has powerful, but yet only prototypical functionalities dedicated to comparing and analyzing the concept maps by teacher. When the learners have created a large number of maps, it could be a challenging task for a teacher to analyze all these maps and give feedback to students. IVA concept mapping tool can automate this task to some extent by transforming all student maps that are associated with the same assignment into one Global Map. This map can be used then for evaluation discussion with whole group or by a single student for comparing his/her concept map with all others at once. Teacher rates the validity of each proposition (consisting of two associated concepts and relation that connects them) in the Global Map using the scale from 0 to 3. Value ‚0' means that the proposition is not valid and ‚3': that the proposition is strongly valid. When the Global map is created and propositions rated, each learner's map will be assessed automatically against the Global Map. While assessing the single learner's map, teacher can change globally given „validity rate" for some propositions, but this is rarely

needed. Automated assessment of concept maps is working better when students are allowed to use only fixed sets of concepts and relation types.

5 Summary

This paper discussed the technological and pedagogical challenges related to development of an interoperable concept mapping tool that is integrated into an open-source Learning Management System IVA. Poor interoperability of popular concept mapping tools (both commercial and open-source) was demonstrated in empirical test. Further, the advantages of XTM as the preferred format for interchanging concept maps between different software packages were explained. Through the descriptive scenarios we tried to explain the design decisions related to the development of IVA concept mapping tool.

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References

Aronson, E., & Patnoe, S. (1997). The jigsaw classroom: Building cooperation in the classroom (2nd ed.). New York: Addison Wesley Longman

Buzan, T. (1991). The Mind Map Book. New York: Penguin

Bartlett, J., Bartley, D., Crisp, S., Fiebig, K., Schild, T., Thorne, C., and Stonebridge, B., 2003. Interoperability Technical Framework for the Australian Government. National Office for the Information Economy, Canberra.

Fischler, H., Peuckert, J., Dahncke, H., Behrendt, H., Reiska, P., Pushkin, D., Bandiera, M., Vicentini, M., Fischer, H., Hucke, L., Gerull, K., Frost, J. (2001) Concept Mapping as a Tool for Research in Science Education. In: Behrendt, Dahncke, Duit, Gräber, Komorek, Kross, Reiska (Eds.): Research in Science Education – Past, Present and Future, p. 217-224. Kluwer Academic Publishers: Dordrecht.

Garrido Picazo, P., Tramullas Saz, J. (2004) Topic maps: an alternative or a complement to concept maps?. In: Concept Maps: Theory, Methodology, Technology. First International Conference on Concept Mapping, Pamplona, 2004, vol. 2, 185-188

Hakkarainen, K, (2003). Emergence of Progressive-Inquiry Culture in Computer-Supported Collaborative Learning, Science and Education, 6 (2), 199-220

ISO 13250. (2000). International Organization for Standardization, ISO/IEC 13250, Information technology — SGML Applications — Topic Maps. Geneva: ISO

IVA (2006). IVA development portal. Retrieved May 18, 2006, from Tallinn University, IVA project Web site: http://www.htk.tlu.ee/iva

Jonassen, D. (1994). Towards a constructivist design model. Educational Technology, 34(4), 34-37

Laanpere, M., Kikkas, K., Põldoja, H. (2005) Pedagogical foundations of IVA Learning Management System. In: eLearning in Higher Education, pp.143-155. Linz: Universitätsverlag Rudolf Trauner

Moore, G.D. (2001). RDF and Topic Maps: An exercise in convergence. In Proc. of XML Europe 2001. Berlin.

Novak, J. D. (1998). Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Paulsen, M.F. (2003). Online Education and Learning Management Systems: Global e-learning in a Scandinavian perspective. Oslo: NKI Forlaget.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

INTERACTIVE CONCEPT MAPPING THROUGH GESTURE RECOGNITION ON A TABLETOP

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Abstract. We present an interactive workspace featuring hand gesture recognition that allows multiple users to collaborate in the creation of a concept map. The workspace integrates web-based and face-to-face scenarios in knowledge-building activities, brainstorming and problem solving sessions. A wiki serves as the repository for knowledge elements, which are presented to co-located users in form of a concept map projected on a meeting table. A computer vision module recognizes multiple hands and fingers on the table surface from an overhead camera, using fingertip detection and tracking algorithm, and map elements can be manipulated using a natural gesture language. Also smart devices, like PDAs or tablets, can be connected to the system and participate in the interaction with their local input. The concept map and the wiki are synchronized in real-time, providing notifications to both co-located and distributed users, allowing a community shared awareness that enhances and enriches the knowledge building experience.

1 Introduction

Knowledge Building (KB) (Scardamelia, M. and C. Bereiter, 1994) refers to creation of new cognitive structures as a result of collective discussion, exchange of previous knowledge and synthesis of ideas. Nowadays such activity is at the core of many processes in different organizational contexts, from scientific research to education and corporate processes. KB is increasingly fulfilled using Computer Supported Cooperative Work (CSCW) tools that provide the users shared environments where the knowledge can be accessed and organized both in distributed and in face-to-face scenarios.

In distributed scenarios, where users can collaborate any time and any place and computers mediate the interaction, the emerging tools for collaborative KB activities are wiki web sites (Cunningham and Leuf, 2001), as demonstrated by the success of the WikiPedia web encyclopedia project. In wikis, the Knowledge Model (KM) (Cañas, Hill et al., 2004) is constructed in form of a dynamic web site where each page can be edited without restrictions by the users, and community-awareness functions stimulate the building process keeping track of versions and supporting discussions.

Wikis are increasingly gaining importance among the core tools of corporate and scientific knowledge management practices (Twiki Success Stories), where they become a living memory of the community internal processes, but they are also used in transient collaborative events, like conferences and meetings. In these scenarios a wiki can be used as a "back channel" to promote discussion and create knowledge artifacts that could persist after the event. In these scenarios the inherent distributed nature of wikis is in contrast with the co-located collaboration that is going on: users must use a personal device to access the knowledge base and temporarily isolate themselves dividing their attention between the wiki and the live event.

There has been interest in applying the wiki collaboration model in face-to-face scenarios where multiple physically co-located users are engaged in shared activities like meetings or brainstorming sessions. Research in this field produced interesting results with the creation of a new class of applications called Single Display Groupware (SDG) (Tse, and Greenberg, 2004). One of the crucial points of these systems, in which user activities are focused on the same information area, is the multiple user interaction that should be carefully designed to favor the natural flow of the session while providing advanced data manipulation functions.

Recent advances in electronic whiteboards brought to the market successful devices like SmartBoard (http://www.smattech.com/) featuring touch-driven interaction on any kind of application, but lacking support for simultaneous users. To overcome this problem, there exist an active research and development on multi-touch devices (Dietz, P.H.; Leigh, D.L, 2001) (Rekimoto, J., 2002) and novel multi-user interaction frameworks (Tse and Greenberg, 2004) (Shen, Vernier, Forlines and Ringel,, 2004). Our goal is to create a bridge between distributed and

face-to-face contexts, designing a common workspace where users can build knowledge exploiting the useful scenario-specific characteristics.

This paper describes the Natural Knowledge Building (NKM) workspace, a hardware and software infrastructure we implemented in order to bring a wiki-style collaboration featuring interactive concept mapping in face-to-face sessions. The interaction metaphor is driven by *concept maps*, as an approach to the visual management of knowledge structures. Co-located users, physically located in the same room, in front of a wall-sized display or a table, can directly manipulate the knowledge elements (Concepts and Relations) synchronized with a wiki. The interaction can happen either using personal devices (PDAs, Tablets) as input methods or through hand gestures performed on the presentation surface.

In order to realize a setup that could be easily installed in existing meeting rooms or conference lounges without expensive equipment, the bare hand interaction is accomplished with computer vision gesture recognition and analysis through the implementation of custom algorithms.

Vision-based interactive systems are unobtrusive to the users, allowing the realization of a *natural interaction*, and normal tables or walls can be easily turned into cheap interactive surfaces to carry on the KB activities.

2 The Natural Knowledge Building Workspace

Wiki collaboration is based on the incremental editing of a collection of web pages, having a meaningful name coincident with the page title, and an hypertextual content providing detail and links to other wiki pages and external resources. While this interface is well suited for distributed users, co-located users typically need a different modality for interacting with data, one that has a higher level of abstraction and is less bound to textual input. This is because in face-to-face sessions the main communication channel is verbal and visuals serve as an aid for symbolic reasoning.

In general, cognitive maps are the natural way of handling knowledge visually, and the concept mapping formalism showed particularly useful and effective in knowledge building activities using collaborative desktop-tools like *CmapTools*. Within our workspace concept maps are used as a visuospatial container of knowledge elements, suitable to portray views of knowledge model subsets.

Every wiki page is focused on a different topic represented by the page name, in this way it can be considered a concept, while the hyperlinks to other pages present in the page contents correspond to relations. The actual textual content of the page, instead, is not directly mapped and shown in the high level map structure.

Wiki	Concept Map
page name	concept
page hyperlinks	relation
page content	-

Table 1. Mapping wiki structures to concept maps

Face-to-face session participants use maps to spatially arrange concepts and visually “draw” the relations between them constructing a form of directed graph and effectively enriching the wiki hypertextual model with spatial meta-data and relation labels. Through this map-building activity users can also introduce new concepts and relations at a visual level and make it available to distributed users. The wiki users can then visualize the maps and use them as a navigation tool to visit a particular view of the knowledge model, detailing and integrating elements introduced in previous sessions.

The multi-user interactivity needed in face-to-face sessions is realized using the SDG component of the workspace called wikiTable.

2.1 *The wikiTable*

The wikiTable is a SDG infrastructure, consisting of a hardware and software setup installed in a shared social space that visually presents Concept Maps on a flat surface, typically a normal desk or table. The system can manage multiple simultaneous inputs coming from different devices in order to make the map interactive. Session participants can interact in two different modalities: using remote devices and manipulating elements with their own bare hands on the table.

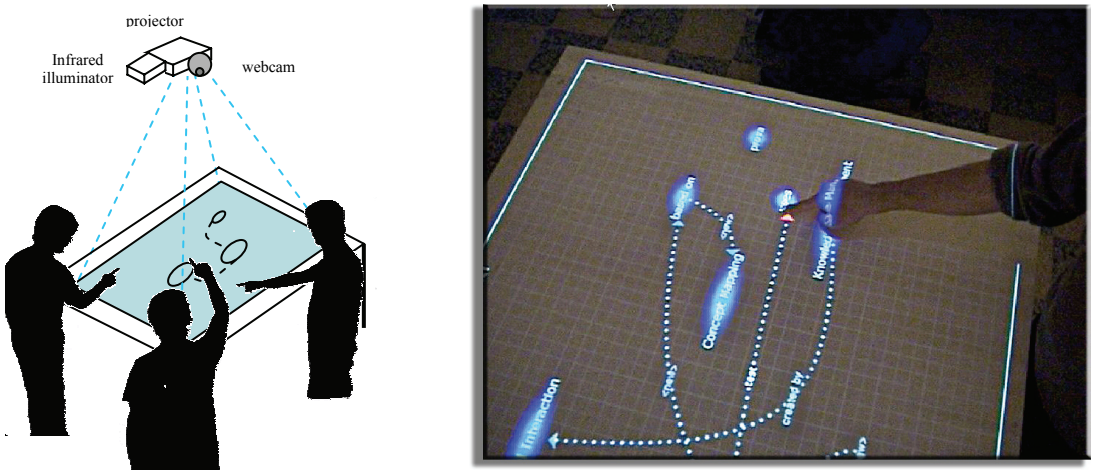


Figure 1. The wikiTable system schematics (a) and a screenshot of the actual application showing the direct manipulation of knowledge structures wih bare hand interaction (b)

Participants can connect to the system using Smart devices (like tablets, PDAs or laptops) equipped with a wireless interface and capable of providing a "pointer" input. Users can join a session through a web page served locally by the embedded wikiTable web server and have their personal pointer projected to the interactive surface. In this manner they are free to move around the table while maintaining their attention focused on the single shared map. The local PDA screen is also employed as a mini-interface through which some actions on the map elements can be engaged, visualizing menus that are dependent on the current pointer position and therefore keeping the shared map interface clean of graphical widgets.

Users close to the table can also use hand gestures to interact with the map elements, gaining a richer and more expressive manipulation language compared with the "point and click" GUI paradigm and a more natural interaction with the visual objects whose affordance becomes similar to that of real objects. Input flows coming from both modalities are continuously merged and the input events are analyzed by device-dependent interaction languages. The outputs of this phase are the following map-manipulation actions carried on the visualized elements:

- Add and delete Concepts.
- Draw, modify and delete Relations between Concepts.
- Spatially Arrange Concepts and Relations labels.
- Move the Map viewport

2.2 *Synchronizing maps with the Wiki*

The wikiTable embeds a component dedicated to the two-way synchronization with the wiki repository. The protocol is composed of simple directives to query and edit the wiki's status and contents, implemented over the http protocol.

During co-located sessions Concept Maps are created as special wiki pages containing the map structure in XML format. In the wiki web interface these pages are then visualized in vector graphics format through a custom XML to SVG conversion (figure 2). In this way also distributed users can use the maps for navigating to the pages containing the Concepts details. Relations between Concepts made explicit in maps augment the knowledge model

and the hypertextual relations drawn in maps are visualized with icons linking to the related map page. This gives wiki users an extra level of meta-data useful for the knowledge building process.

If page A includes a link to page B, and one or more maps exist in which relations between A and B have been defined, links to the involved maps are presented next to the normal hyperlink to B and the relation name is shown as a tooltip on the map link. Wiki systems support tags that expand in the page text and layout. Custom tags can be defined to embed in the page panels in which all the relations from/to A are listed, introducing another navigation tool.

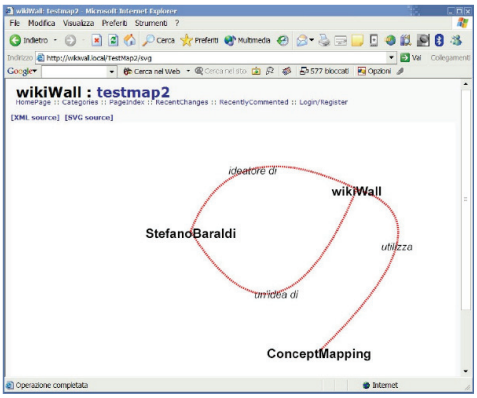


Figure 2: maps are rendered in the wiki through an XML to SVG conversion that retains their visual layout.

Face-to-face users are notified about asynchronous activities performed by distributed users. When the wiki pages are accessed or changed, visual notification are presented on the wikiTable. New Concept and Relation elements are shown as visual objects slowly fading away, in this fashion co-located users can consider concept integration in the current map. Other kinds of visual notifications inform session participants that a distributed user has logged in or out of the wiki.

3 Gesture based interaction with the map

Natural Interaction claims that visual objects, in this case map elements, should be manipulated like real objects. This is accomplished using gesture recognition of multiple hands and fingers on the table by means of computer vision algorithms applied to the video stream of the surface. The input events are interpreted from the posture of multiple hands moving on the table, their orientation and the state of the stretched-out fingers.

Concepts and Relations are represented by their own textual labels. Concepts are created by selecting them from the KM or by entering text directly, this is accomplished using a shared virtual keyboard widget which recognized key presses of single-fingered hands on key areas (figure 3a). The created words can instantly become Concepts (creating a page for in the wiki) or remain in a neutral state, this way they can be used as notes or later to rename a Relation.

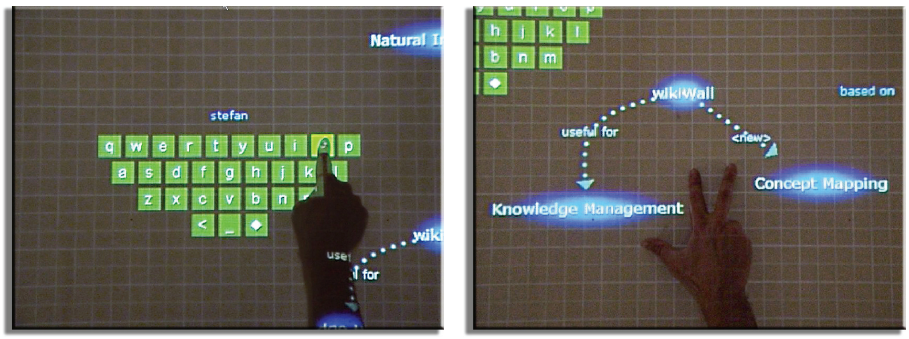


Figure 3: (a) virtual text entry widget for label creation, (b) the Map scrolling action.

Concepts can be moved around (figure 4a) grabbing them with a two-finger gesture. Once grabbed, the object is controlled only by the user starting the action. A change in the gesture causes the action to end and the object to be positioned in the reached position.

Relations are created engaging a Concept with a single-finger gesture and moving the created arrow until it collides with another Concept (figure 4b). The resulting line is a spline curve with a single control point in the middle represented by the Relation textual label. Existing relations can be modified in a similar way, grabbing their final arrow and moving it next to another Concept.

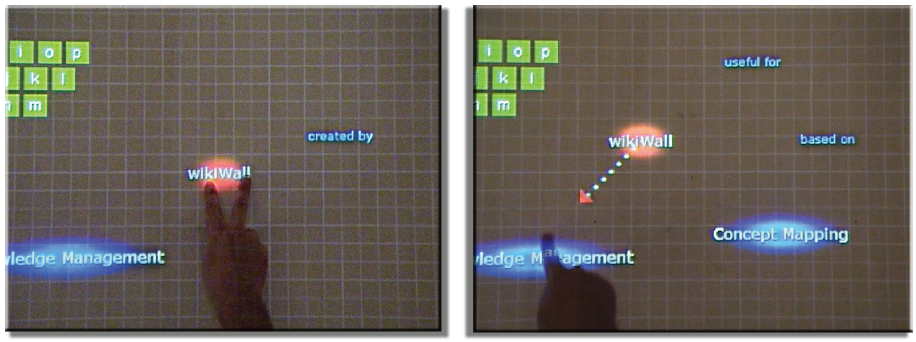


Figure 4: (a) moving a Concept, (b) drawing a Relation between Concepts.

Relation labels can either be implicit (suggested by the KM from hyperlinks in the Concept detail page) or explicit by assigning a textual label grabbing a free word and bringing it on the label region (figure 5b).

Once created, Relations arcs are bound to the positions of the belonging Concepts, only the label can be moved with the same two-finger gesture to better arrange the graph.

The Map viewport can be moved (figure 3b), allowing the building of large maps, with a specific three-fingers gesture and the map position under the hand is used as a reference point for the scrolling.

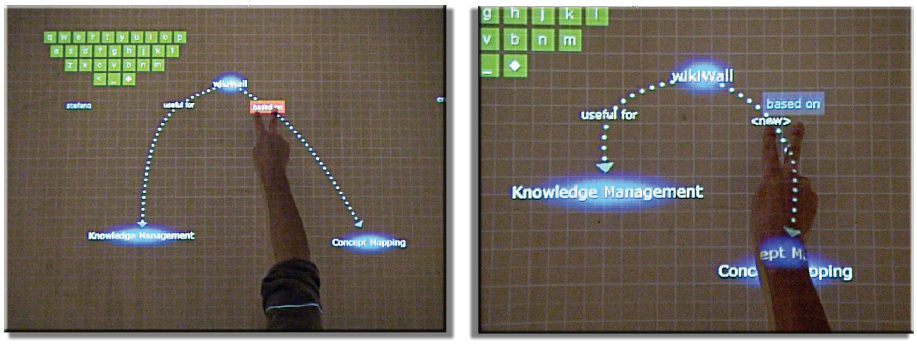


Figure 5: (a) moving relation label to modify the arc appearance,
(b) renaming a relation with a new textual label.

3.1 Finger detection algorithm

The *wikiTable* setup embeds a computer vision system to perform the needed gesture recognition process. In our setup a ceiling-mounted overhead camera targets the table area and captures video that is analyzed by means of image processing techniques. The area is lit by an infrared illuminator and the camera is equipped with a near infrared (830nm) pass filter, in order to capture only the users limbs and not the projected graphical interface, allowing a simpler analysis phase.

The image is first segmented in background and foreground regions through a common *background subtraction* algorithm and the obtained foreground mask is processed by a *finger recognition* algorithm based on the work of J.Letessier, F.Bérard and C.Hardenberg (2001,2004) for a quick early classification of finger point candidates on the whole foreground mask. For the subsequent phases we developed our own *association*, *tracking* and *classification* techniques.

Fingers are tracked over frames with a *nearest-neighbour* association approach extended with position prediction using a simple weighted linear predictor, this technique helps reducing the number of mismatches between different hands' fingers. Hands are then created clustering compatible fingers according to their position and direction, and applying heuristics and estimations on the hand morphology.

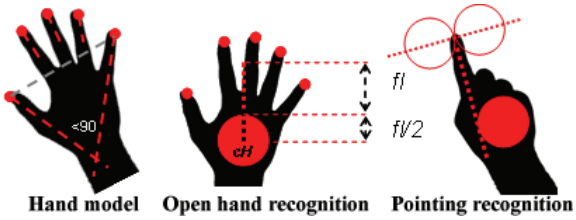


Figure 6: model used in hand recognition

A maximum of 5 postures are then recognized, named *p1* (hand with single pointing finger) to *p5* (opened hand) according to how many fingers are extended. We use the posture classification to build a simple sign language where the semantics is not based on the hand shape, but the *number* of stretched out fingers.

The acquisition of postures during time creates a flow of input atoms that are passed to the application controller module. The next step is the interpretation of the input flow by means of a chosen interaction language to generate the application actions.

In choosing the hand interaction language we were driven by the nature of the manipulated objects on the table: both *Concept* and *Relation* elements have the textual label as reference area and their size is comparable to an opened hand on the table.

As a general principle to provide a *natural interaction* we choose to keep the mapping between the interactive events and the actions as direct as possible. This means that we did not use menus and operations were defined by simple gesture transitions, of course this constraint forced us to find meaningful mappings between gestures and actions.

We used a language of three *gestures* (see table 2) considering also transition times in order to detect the persistence of a posture. This is needed because in our implementation no other sensor but the camera is used, and therefore the contact event of the hands touching the table is not detected. The following table illustrates the mappings for actions on the Map elements:

gesture		**context**	**action**
	Posture *p1*	Concept, Relation arrow	Create/modify relation, Write text
	Posture *p2*	Concept and Relation labels	move
	Posture *p3*	an empty area of the Map	move Map viewport

Table 2: gesture language.

In general we considered *Gesture1*, the typical pointing hand, to be the most useful for directly accessing the functions of a two-dimensional visual element. The reason for this assumption is that *Gesture1* is commonly used to highlight or select an element, both in non verbal communication and in many touch interfaces, and it is the most precise giving a single point of reference. Therefore, in our language *Gesture1* has been used to create new relations and modify existing ones, and also to press the keys of the virtual keyboard. *Gesture2* is used to grab and move concepts and relation labels in the map. The two fingertips define a line region between them that is enough precise to manipulate also the smallest possible objects. *Gesture3* is dedicated to scrolling the Map viewport in order to show other parts of the Map. We used this gesture because the map scrolling is performed on an empty area of the map, and a precise reference point is not needed for the relative movement.

For the deletion action we used the common metaphor of moving an element on a visual recycle bin object. Even if this is a GUI metaphor it is compatible with our need for a direct mapping of actions.

4 Results and future work

We tested the hand interaction system with more than thirty people of different age and computing skills during a six months period. Users were given the task to arrange a reference map from a spatial layout to another. A quick training on the interaction language was provided, in which users were shown the interface usage. Then we observed the video recordings of the map-building session and for every action we determined the average *success ratio* (measuring the times in which the action was successfully recognized by the system) and the average *time duration* (indicating the average time spent to complete the action).

For the duration we measured time elapsing from the first moment in which the user intention was clear, up to the time in which the task was succesfully completed. These measures are in direct relationship respectively with the effectiveness and efficiency of the system expounded.

We proceeded with two test scenarios: a single user scenario, and a co-located scenario in which three users were asked to complete the task. The results of the observations are shown in table 3.

action	***avg. success ratio***		***avg. time duration (sec)***	
	single	***multi***	***single***	***multi***
create label or concept	98%	91%	6.7	8.4
create relation	94%	87%	5.6	7.5
move object	99%	93%	5.2	5.9
scroll viewport	82%	63%	6.3	15.3

Table 3: results of user observations

Single users managed to quickly arrange the map and were only annoyed by the time persistence of 500ms to simulate the click. Multiple users were at first reluctant to interact simultaneously, but then found the co-located map-building experience to be exciting. The only one-user action, viewport scrolling, created some confusion. We believe that a careful design of tabletop system should avoid such exclusive actions.

With the proposed Natural Knowledge Building workspace and the *wikiTable* SDG system, we addressed the integration of two different collaboration contexts: face-to-face sessions and web-based knowledge building using *wikis*.

Further work is ongoing, concerning the definition of other map-manipulation actions (like zooming and map nesting) and a real-time synchronization between remotely placed tables in a scenario where multiple groups of co-located users are geographically displaced when working on the same maps.

References

Scardamelia, M. and C. Bereiter, "Computer Support for Knowledge-Building Communities." *The Journal of the Learning Sciences* ,3(3): 265-283, 1994.

W. Cunningham and B. Leuf, *The Wiki Way*, Addison-Wesley, Boston, MA, USA, 2001.

A. J. Cañas, G. Hill, R. Carff, N. Suri, J. Lott, T. Eskridge, G. Gómez, M. Arroyo, R. Carvajal, "CmapTools: A Knowledge Modeling and Sharing Environment", *Concept Maps: Theory, Methodology, Technology, Proceedings of the First International Conference on Concept Mapping*, Universidad Pública de Navarra: Pamplona, Spain. p. 125-133, 2004.

Twiki Success Stories, *http://twiki.org/cgi-bin/view/Main/TWikiSuccessStories.*

Tse, E. and Greenberg, S. "Rapidly Prototyping Single Display Groupware through the SDGToolkit." *Proc Fifth Australasian User Interface Conference*, Australian Computer Society Inc., p101-110, 2004.

Smart Technologies. Smart Board. *http://www.smattech.com/*

Dietz, P.H.; Leigh, D.L., "DiamondTouch: A Multi-User Touch Technology", *ACM Symposium on User Interface Software and Technology (UIST)*, ISBN: 1-58113-438-X, p. 219-226, 2001.

Rekimoto, J., "SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces", *Proceedings of CHI'02 Conference on Human Factors in Computing Systems: Changing our World, Changing Ourselves*, ACM Press, pp.113-20, 2002.

Tse, E. and Greenberg, S. "Rapidly Prototyping Single Display Groupware through the SDGToolkit." *Proc Fifth Australasian User Interface Conference*, Australian Computer Society Inc., p101-110, 2004.

Shen, C, Vernier, F., Forlines, C. and Ringel, M. "DiamondSpin: An extensible toolkit for around-the-table interaction." *In Proceedings of CHI'04, ACM Press,* p. 167-174, 2004.

J.Letessier, F.Bérard, "Visual tracking of bare fingers for interactive surfaces", in *Proceedings of the 17th annual ACM symposium on User interface software and technology (UIST'04)*, 2004.

C.Hardenberg, F.Bérard, "Bare-Hand Human-Computer Interaction*", ACM Workshop on Perceptive User Interfaces*, 2001.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

JUMP-STARTING CONCEPT MAP CONSTRUCTION WITH KNOWLEDGE EXTRACTED FROM DOCUMENTS

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Abstract. Online documents provide a rich information resource for aiding the generation of concept-map-based knowledge models, but analyzing resources to select concepts and links is a time consuming task. This paper describes ongoing research on harnessing the information in unstructured textual documents, using information extraction algorithms, to generate a preliminary version of a concept map from a text document, for human refinement. The paper presents strategies for this task, implemented in an initial algorithm. The concept extraction phase of the algorithm has been evaluated with encouraging results.

1 Introduction

Given the large amount of information available online and the effectiveness of modern Web search engines, documents on the Web provide a useful starting point for humans gathering information about particular domains. Concept maps provide a useful medium for sharing such information in a concise and accessible form, making knowledge models based on concept maps (Novak & Gowin, 1984) a promising vehicle for knowledge sharing. Unfortunately, generating such knowledge models may require considerable effort to determine which concepts and relations to include. In some settings, this effort carries its own benefits, as when students increase their own understanding by performing the knowledge modeling process. However, to further the deployment of knowledge models, especially for large domains, it is desirable to facilitate the concept map generation process, through the use of automated systems to support knowledge model generation (e.g., Cañas et al. 2003, 2004b, Leake et al. 2004).

Natural Language Processing techniques are successfully used to automatically extract information from unstructured text documents through a detailed analysis of their content, often to satisfy particular information needs, such as providing a list of facts related to some event or topic or a specific answer to a question (e.g., Jackson & Moulinier, 2002). In this paper, we present ongoing research on applying such methods to automatically help concept map builders to exploit on-line documents, by applying information extraction procedures to automatically produce a preliminary version of a concept map, as a starting point for humans to adapt and eventually integrate into a knowledge model. The current goal of this work is not to produce a human-quality concept map from a given document automatically, which is a hard problem for long-term research. Instead, the goal is to perform preprocessing to speed up the generation of maps and integration of document information, for later refinement by a person or by another automatic process. At the same time, we expect that steps towards the current goal will contribute towards the long-term goal of autonomous concept map generation.

The paper is organized as follows: Section 2 presents some characteristics of concept maps which must be reflected in the document processing algorithm. Section 3 presents our algorithm and summarizes its current implementation. Section 4 describes an evaluation of the system, focusing on the concept extraction process which we see as the core of the required process. Section 5 presents some related work and Section 6 discusses some future directions for this project.

2 The Nature of Concept Maps

Ideally, automatically-generated concept maps would resemble the concept maps which might be constructed by a person with access to the same information. Consequently, we first consider already-known general features of "well-constructed" human-made concept maps, to guide design and evaluation. Novak and Cañas (2006) identify a number of concept map characteristics, involving both structure and content of the map, each of which has ramifications for automatic concept map generation.

Hierarchy of concepts: Besides extracting the concepts, a generation algorithm must sort them relative to their importance to the source document.

Different levels of abstraction and detail: Concept maps may be written in different levels of abstraction and detail depending on many conditions, i.e. expertise of the user or desired level of complexity. An ordered concept list may also be used to select the desired level of detail.

The information in propositions: In its simplest form, a concept map is a set of propositions. The concepts are mostly noun phrases, ideally consisting of few words that represent a particular concept. Concepts usually represent physical or abstract objects or entities; as a result, their labels usually contain nouns and adjectives. The linking phrases are usually verb or prepositional phrases that link concepts, so they usually have verbs and adverbs. A proposition is not necessarily a full sentence. This indicates that high granularity may be required when parsing the text.

Subjectivity: Both a concept map and a document represent the understanding or perspective of the author on a particular subject; the goal of generation is to reflect that perspective.

Informality: Similarly to documents, concept maps are not intended to provide formal presentations of concepts, definitions and semantic relations with other concepts. Therefore, the knowledge provided by the author may be captured in an informal textual form, without extracting formal relationships.

3 Extracting Knowledge from a Document to Build a Concept Map

Natural language processing techniques are used successfully on a variety of information extraction tasks (Harabagiu et al., 2005; Orkut et al., 2001; Alves et al., 2002). Each of these tasks requires a different treatment of the source depending on the particular information need and, in some cases, previous knowledge about the target context. Part of our research examines how to adapt and use the existing information extraction algorithms to our concept mapping task. For example, developing a useful concept map may require deciding how to select the granularity of entities (e.g., *"President of The United States of America"* might be best represented as a single concept in some contexts, and in terms of concepts for *"President," "United States,"* and *"America"* in others). An interesting long-term research question is how the requirements for language processing to jump-start concept map generation differ from those of more traditional NLP tasks. For example, when the goal is interactive support, perfect analysis is not needed, but, the suggestions must be sufficiently useful for the knowledge modeler to accept and benefit from the system.

Analyzing a document to extract information for a concept map requires two main extraction steps. The first is to identify and name the concepts in the text. Here we refer to "concepts" in a broad sense, meaning all the objects and entities mentioned in the document. These appear primarily as objects and direct/indirect objects in sentences, and will be noun phrases. The second is to identify and name relationships for linking phrases. We expect these to be suggested by possible syntactic dependencies between objects, with the connecting verb phrases in the sentences containing possible semantic relations which may correspond to the linking phrases of a future concept map.

The two extraction processes need not be solely bottom-up; they could use existing information about the target knowledge model or incoming document stream to bias the acquisition of concepts and their relations. However, in this paper, we focus on extracting information based on the document alone. This facilitates evaluation by eliminating potential sources of bias and noise based on background knowledge, and tests the domain-independent capabilities of the extraction algorithm to provide the first iteration of a concept map that could later be expanded and refined by a person or by automatic methods.

As a starting point, our current work focuses on the problem of generating a single concept map from a single document. This is a simplification because large documents may contain different "topics" or "themes" appropriate for producing several concept maps, and, several documents may refer to the same topic, making them reasonable to merge into a single concept map. We expect that an algorithm for the *1-1*

case will be scalable to such *n*-to-*m* transformations, by introducing a topic segmentation step that may be included before the process starts, splitting the document into *n* documents. Likewise, merging of information across maps could be addressed by having common concepts and relations merged into *m* distinct concept maps once all individual documents are processed. The problem of processing raw text documents is independent to the problem of splitting and merging concepts into coherent, independent concept maps.

We assume the incoming document is "well-written" and that it contains the description of a concept or set of concepts. Figure 1 summarizes the steps of our current algorithm. The steps of the algorithm, and the specific techniques we have applied in their implementation, are described in more detail below.

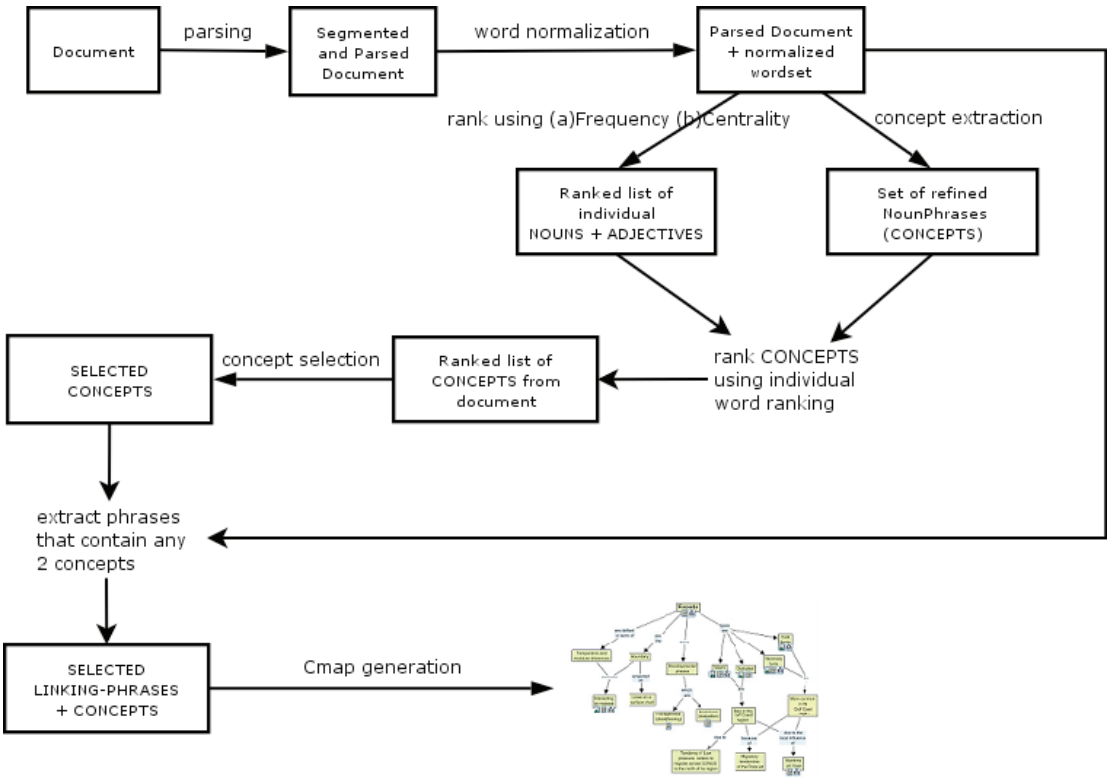


Figure 1. Procedure to construct a concept map automatically from a document.

Step 1. Document segmentation and parsing: The document is first preprocessed by an ad hoc sentence boundary detection algorithm based on regular expressions. Next, each individual sentence is parsed using Charniak's algorithm for a deep syntactic analysis (Charniak, 2000; Charniak et al., 2005). This step simultaneously tags each word with its part of speech, produces a parse tree for the sentence, and exposes the dependencies between the constituents. A shallow parser with linkage information could have been used in this step, but the subtree for each noun phrase is useful for adjusting the level of granularity when generating the concepts.

Step 2. Word normalization: Documents contain morphological variations of words that refer to the same entity, and may use multiple synonyms. The normalization step splits words into disjoint equivalence classes, in which two words *a* and *b* are considered equivalent if

(1) $POS(a) = POS(b)$

(2) $stem(a) = stem(b)$ or a *synonym* b,

where *POS(a)* is the part-of-speech of *a*: noun, verb, adjective,… and *stem(a)* is the basic form of the word after all affixes are removed. Porter's (1980) algorithm is used for word stemming and WordNet (Fellbaum, 1998) to determine the synonymy relation. We note that occasional conflicts may arise from the definition of equivalence, because the synonym relation is not transitive. Consequently, the definition may potentially

consider a word to belong to two different sets; in that case, the algorithm arbitrarily assigns it to either one. We do not expect this to have a significant impact in performance, because there is a 50% chance of picking the right set and this situation is not expected to occur frequently. Once the algorithm identifies the word equivalences, it tags each word with its class, for use to compare words in later steps.

Step 3. Individual word ranking: The next step, assigning weights to individual words, is needed for the later calculation of the weights of noun phrases. Several term weighting methods have been proposed for calculating term importance (Salton et al., 1988; Hulth, 2003), most relying on the relative importance of terms across a collection of documents. Such methods are not suitable for our task, because our aim is to develop methods to process the source document independently from other incoming documents or documents in the knowledge model, as a step towards solutions usable to jump-start the earliest steps of concept map generation, when additional information sources will not be available. Given this constraint, we used simple term frequency in the document, a method which has achieved some success when additional context information is unavailable (Salton et al., 1988). Our system considered only nouns and adjectives, as those are the most common parts of speech in concept-describing phrases. The analysis produces a list of words that is ordered by descending weight.

Step 4. Concept extraction: Starting from the parsed document and the normalized word set, the algorithm produces a set of noun phrases which will become the candidate concepts. The approach to this problem takes into account that: (1) ideally concept labels consist of a small set of words and (2) similarly to the word normalization step, noun phrases in a document with different surface forms may refer to the same concept.

Our algorithm starts by finding noun phrases that are closer to the leaves, without nested complex structures. In a parse tree, these are complex noun phrases, typically the object or direct object of a sentence, containing smaller noun phrases as its constituents. Although these large noun phrases reflect the dependencies of the sentence better, we need the smaller noun phrases instead because concept labels usually have a reduced number of words.

After the "minimal" noun phrases have been identified, the algorithm finds possible equivalences between them. It considers two noun phrases equivalent if (1) all nouns and adjectives in one are contained in the other and (2) this equivalence is not in conflict with any other. For example, given {*"President"*, *"President of Russia"*}, *"President"* and *"President of Russia"* are considered equivalent, but this is not true for {*"President"*, *"President of Russia"*, *"President of France"*} because the equivalence conflicts with *"President of France"*.

Step 5. Ranking concepts using the individual word ranking: Next, the set of extracted noun phrases is ranked using the ordered list of nouns and adjectives. This ranking ultimately will help selecting appropriate concepts to produce a clearer and more complete concept map. The rank of a noun phrase is given by the highest rank of its nouns and adjectives, with ties broken by the rankings of other words in the phrase if possible. The position of a concept in the ranking represents the relevance to the document's content.

Step 6. Concept selection: For short focused documents, it may be desirable to generate maps corresponding directly to the document itself. For longer or less focused documents, it may be desirable to limit the number of concepts presented in order to avoid overwhelming the user. A number of heuristics were assessed with informal tests: select the first n concepts, select a number of concepts incrementally until the concept map reaches certain size or cohesiveness, etc. The evaluation in the following section does not perform concept selection; instead, all concepts are used to construct the concept map.

Step 7. Linking phrase extraction: This phase tags the original parse trees with the selected concepts, extracting all pairs of concepts that have an indirect dependency link through a verb phrase. We presume that these phrases show relations between the concepts, so we extract those as the linking phrases. These phrases are marked in the trees.

Step 8. Concept map generation: The final step gathers the information from the tagged parse trees to construct the concept map: the selected noun phrases become the concepts and the connecting verb phrases are the linking phrases. The current system does not produce a graphical representation of the concept map (layout is a non-trivial issue). However, some auto-layout capabilities are already implemented on concept mapping tools, as in CmapTools (Cañas et al., 2004a) from the Institute for Human and Machine Cognition, which could be used to produce an initial graphical representation of the concept map.

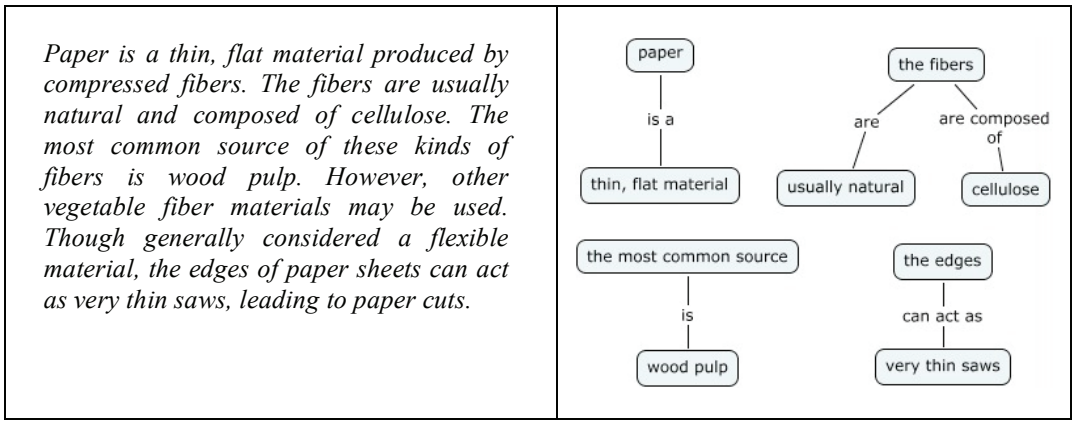


Figure 2. Example of system output from processing a short document

Figure 2 illustrates the algorithm's output. All concepts linked by the algorithm are shown; isolated concepts were removed for legibility. Note that some prepositional forms in the source document are not yet being used as linking phrases, which is a current deficiency of the algorithm and part of our future work.

4 Experimental setup and Results

Our evaluation focuses on Steps 1 through 5 in the previous section, testing the algorithm's performance extracting an ordered list of concepts as the starting point for constructing a concept map. To test the quality of the concept list produced, we started from an existing knowledge model already annotated with documents, and tested the ability of the algorithm to recover the concept map from the documents alone. Each document is processed individually, with its concepts automatically extracted using the described procedure. The evaluation is then based on match between the identified concepts and the set of concepts to which each document was originally attached. Although we are considering this as a portion of the general concept generation process, we note that the test task is important task in its own right: It could be used as to automatically index documents for a multimedia knowledge model, by taking a document and suggesting concept map nodes to which the document should be attached.

The experimental design is based on some premises about the association between concepts and attached documents in the expert knowledge models. First, we assume that if a document was attached to a given concept *C* in the expert's knowledge model, it is because the document contains either a description of *C* or relevant information about it, and therefore that *C* must be one of the concepts which should be ranked highly in the document. Second, we assume that each document is linked to the most related set of concepts in the enclosing concept map, but to no others. In other words, a concept *C* would not link to a document that is not relevant, and if some document is relevant to *C*, then a link between them will exist. These assumptions may not always hold, because we are processing data that may have errors and noise, but those are conditions that can generally be found in well constructed knowledge models.

In the test, a document *D* is selected for attachment to a concept *C* if *C* occurs in the first n concepts extracted from *D*. If the document is attached correctly (i.e., the attachment matches the choice made in the initial knowledge model), this supports the quality of the ranking in the list, because (1) the concept is in the list and (2) the concept appeared as one of the first concepts in order of relevance. We note that this

may be seen as a stringent test, because the algorithm is only credited if it replicates the assignment in the original knowledge model, even though it is possible that alternative placements would be acceptable.

As test data, we selected 80 documents at random from those in STORM-LK knowledge model (Hoffman, R. R. et al., 2001). The system processed each document to extract the concept ranking, and, the documents were "reattached" to the concepts in the knowledge model as described above. Because our procedure permits documents to be attached to multiple concepts, we used the average precision/recall for all the documents to evaluate the results. We evaluated the algorithm in two ways: (1) using only the concept that ranked first and (2) using the concepts that ranked first and second. The algorithm was tested with and without the stemming procedure to measure the impact of this normalization. Our algorithm's performance was compared to a baseline algorithm, which attaches a document to a concept if the concept contains any of the nouns or adjectives in the document.

Baseline		*Without stemming – Top 1*		*With stemming – Top 1*	
Precision	Recall	Precision	Recall	Precision	Recall
0.267	0.890	0.467	0.537	0.578	0.712

Baseline		*Without stemming – Top 2*		*With stemming – Top 2*	
Precision	Recall	Precision	Recall	Precision	Recall
0.267	0.890	0.408	0.707	0.553	0.848

Table 1. Results for algorithm evaluation

Table 1 shows the results of the testing. The results suggest that using noun phrases produced by the algorithm increases precision compared to using the individual words from the baseline. Stemming increased overall performance, and precision was improved by using only the top-1 or top-2 concepts. Even when the matching is so strict, the recall average is between 53% and 84%. In general, the algorithm successfully associated the documents to the original concepts, which is promising for its use as the basic domain independent algorithm to extract concepts.

We note that because the final goal of the project is to aid generation of new concept maps, rather than to attach documents to concept maps, the algorithm did not use information in the maps to provide top-down guidance. We expect that performance for the document annotation task would be improved by using such information.

5 Related work

5.1 Concept generation to provide suggestions to aid concept map generation

Recent research has aimed at retrieving relevant documents from the web (Leake et al., 2004) and at annotating existing knowledge models with those documents (Reichherzer & Leake, 2006). However, this work does not aim to extract individual concepts from documents, instead focusing only on a global match between document terms and concept labels. A number of successful concept suggesters have been developed to provide the user with a list of relevant terms to extend a concept map (Cañas et al., 2004b; Leake et al., 2004). Because a byproduct of our algorithm's processing is a list of concepts extracted from a document, ordered by relevance, our approach might potentially form the basis of another suggester of concepts, as discussed later in this paper; the key difference that our approach is not term-based but "concept-based".

5.2 Other solutions to produce concept maps from documents

Some prior work attempts to construct concept maps or similar representations automatically from text. Alves A. et al. (2002) uses WordNet to extract an initial hierarchy of nouns from a document to build an initial list of concepts, followed by several user feedback iterations to deduce relationships between pairs of concepts and hypothesize about their relations. Clariana, R. et al. (2004) present an approach which relies

on a predefined list of domain specific concepts provided by an expert. It considers two concepts to be related if they occur in the same sentence, but does not suggest possible linking phrases. On the other hand, Rajaraman K. et al. (2002), focuses word sense disambiguation. Once the meaning of nouns and verbs are resolved, it searches for Noun-Verb-Noun structures in the sentences, which become the concept – linking phrase relations.

Our approach is different in two important aspects. It uses the syntactic structure of the sentences and dependency information to find relations between the words. The relations are not retrieved from predefined ontologies, but are generated from the document itself. This enables the approach to be applied in any domain, without initial knowledge capture. In addition, it is more sensitive to the intentions of the document author. For example, even if two concepts are related in a particular the author might have intentionally ignored that relation, because it did not correspond to the desired level of abstraction. In addition, our algorithm produces concepts based on noun phrase structures rather than on individual words, making the concept labels more complete; capturing these from documents may also make them closer to the concept descriptions produced by a person. Such subjective characteristics, as well as the overall usefulness of the system to support users, are subjects for future human subject evaluations.

6 Summary and Future Work

This paper presents ongoing research on bootstrapping the concept map generation process, by generating preliminary concept maps based on documents. We have fully implemented an initial algorithm for this process, and have evaluated one central component, a domain-independent algorithm to extract from a document a list of concepts, ranked by their relevance to the source document. The algorithm uses a deep syntactic parse to select of noun phrases with different levels of granularity when desired. A basic term weighting approach is used in this first version of the process, and is a target for refinement, but an initial evaluation of the algorithm shows encouraging results.

In future work, we expect to study and refine aspects of the algorithm such as the term weighting approach for individual words. For example, we have done initial tests of an algorithm proposed by Mihalcea et al. (2004), which constructs a graph representation of the document to compute individual term scores using a modified version of PageRank. While results were mixed, we plan to explore this in further. We also plan to evaluate the impact of alternative normalization procedures on performance, such as name-entities co-reference and anaphora resolution. By the same token, a more accurate solution to conflicting synonyms might be to use a word sense disambiguation algorithm, but only for the words in conflict. There is no need to disambiguate the sense of all words, as we assume that if no synonym conflict exists the word was placed in the correct set. An algorithm has been developed to disambiguate words in concept maps (Cañas et al., 2003), but it cannot be used at this point because for our task, the conflicts need to be solved before the concept map is formed. In addition, we intend to include other syntactic forms as candidate linking phrases, to test the linking phrase extraction phase, which we expect to require a human subjects experiment, and to explore other heuristics to weight the noun phrases based on the term weights.

Once the algorithm is refined, we will consider two problems. The first is how to use the information extracted from a set of related documents to produce a set of concept maps. This may require the segmentation of documents in smaller topics or themes, and also the identification of common themes across documents. The second is how to apply additional information beyond the document itself. This information will come from (1) the concept maps in the target knowledge model, to bias the extraction of concepts and linking phrases and (2) crossed information on other related documents and documents existing in the knowledge model. We expect this information not only to allow more accurate construction of the concept map, but also to further the possibility of automatically attaching documents to concepts, if desired.

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8 References

Alves, A., Pereira, F., Cardoso, A. (2002). *Automatic Reading and Learning from Text*. Proceedings of the International Symposium on Artificial Intelligence.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004a). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Cañas, A. J., Carvalho, M., Arguedas, M., Leake, D. B., Maguitman, A., & Reichherzer, T. (2004b). Mining the Web to Suggest Concepts during Concept Map Construction. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. of the 1st Int. Conference on Concept Mapping*. (Vol. I, pp. 135-142). Pamplona, Spain: Univ. Pública de Navarra.

Cañas, A. J., Valerio, A., Lalinde-Pulido, J., Carvalho, M., & Arguedas, M. (2003). *Using WordNet for Word Sense Disambiguation to Support Concept Map Construction*. Proceedings of SPIRE 2003: International Symposium on String Processing and Information Retrieval, Manaus, Brasil.

Charniak, E. (2000). *A Maximum-Entropy-Inspired Parser*. Proceedings of NAACL-2000.

Charniak, E. & Johnson, M. (2005). *Coarse-to-fine n-best parsing and Maximum Entropy discriminative reranking*. ACL'05.

Clariana, R. et al. (2004) *A Computer-Based Approach for Translating Text into Concept Map-like Representations*. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Fellbaum, C,. ed. (1998), *WordNet: An Electronic Lexical Database*, MIT Press.

Harabagiu S., Moldovan D., Clark C., Bowden M., Hickl A., Wang P. (2005). *Employing Two Question Answering Systems in TREC 2005*. Proceedings of the 14th Text Retrieval Conference.

Hoffman, R. R., Coffey, J. W., Ford, K. M., and Carnot, M.-J. (2001). *Storm-LK: A human-centered knowledge model for weather forecasting*. The 45th Annual Meeting of the Human Factors and Ergonomics Society, Minneapolis, MN, USA.

Hulth, A. (2003). *Improved automatic keyword extraction given more linguistic knowledge*. The 2003 Conference on Empirical Methods in Natural Language Processing, Japan.

Jackson, P. & Moulinier, I. (2002) *Natural Language Processing for Online Applications*. Philadelphia: John Benjamins Publishing.

Leake, D. B., Maguitman, A., Reichherzer, T., Cañas, A. J., Carvalho, M., Arguedas, M., et al. (2004). Googling from a Concept Map: Towards Automatic Concept-Map-Based Query Formation. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 409-416). Pamplona, Spain: Universidad Pública de Navarra.

Mihalcea, R. & Tarau, P. (2004). *TextRank:Bringing order into texts*. In Proceedings of EMNLP.

Novak, J. D. & A. J. Cañas (2006). *The Theory Underlying Concept Maps and How to Construct Them*. Technical Report IHMC CmapTools 2006-01. Florida Institute for Human and Machine Cognition.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

Orkut, B., Garcia-Molina, H., Paepcke, A. (2001). *Seeing the Whole in Parts: Text Summarization for Web Browsing on Handheld Devices*. The 10th International WWW Conference. Hong Kong, China.

Porter, M.F. (1980). *An algorithm for suffix stripping*, Program, Vol 14, Number 3. pp 130−137.

Rajaraman, K. & Ah-Hwee Tan. (2002). *Knowledge Discovery from Texts: A Concept Frame Graph Approach*. The 11th International Conference on Information and Knowledge Management.

Reichherzer, T. & Leake, D. (2006). *Towards Automatic Support for Augmenting Concept Maps with Documents*. In A. J. Cañas, J. D. Novak (Eds.), Concept Maps: Theory, Methodology, Technology, Proc. of the 2nd Int. Conf. on Concept Mapping. San Jose, Costa Rica: Universidad de Costa Rica.

Salton, G. & Buckley, C. (1988). *Term-weighting Approaches in Automatic Retrieval*. Information Processing and Management. Vol 24, Number 5.

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KEA: A KNOWLEDGE EXCHANGE ARCHITECTURE BASED ON WEB SERVICES, CONCEPT MAPS AND CMAPTOOLS

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Abstract. The CmapTools program, and concept mapping in general, have seen a steady growth in usage in the last few years. With new users come new requirements and needs for the software that we can't always satisfy. Until now, the CmapTools architecture has been relatively closed to third party developers. In this paper we report on a new open architecture, KE (Knowledge Exchange Architecture), that provides the data and procedural framework to allow third party developers to design programs that interact with the CmapTools suite of programs. KEA consists of a portable, standard file format for data exchange (CXL), and a set of protocols for retrieving, storing, and manipulating Cmap information. We also describe how KEA was implemented and provide three sample client-server applications illustrating the steps we have taken toward the completion of this implementation.

1 Introduction

The CmapTools program (Cañas et al., 2004) was designed to be a simple to use but powerful environment that facilitates collaboration and sharing during the construction of concept map-based knowledge models (we consider a knowledge model to be a set of concept maps (Cmaps) and associated resources about a particular domain of knowledge (Cañas, Hill, & Lott, 2003). The software was designed to have a low threshold, making it easy to learn for new and naïve users, but at the same time to have a high ceiling, enabling sophisticated and expert users to develop large, complex knowledge models.

The use of CmapTools is experiencing rapid growth worldwide (see http://pictor.ihmc.us/gl for a live world map of CmapTools installations). Users are constantly discovering innovative ways of doing concept mapping and using the CmapTools software. The constant growth in the use and usages of CmapTools leads to needs for new ways to manipulate Cmaps. Some of these needs are very specific to a small group of users, or for a variety of

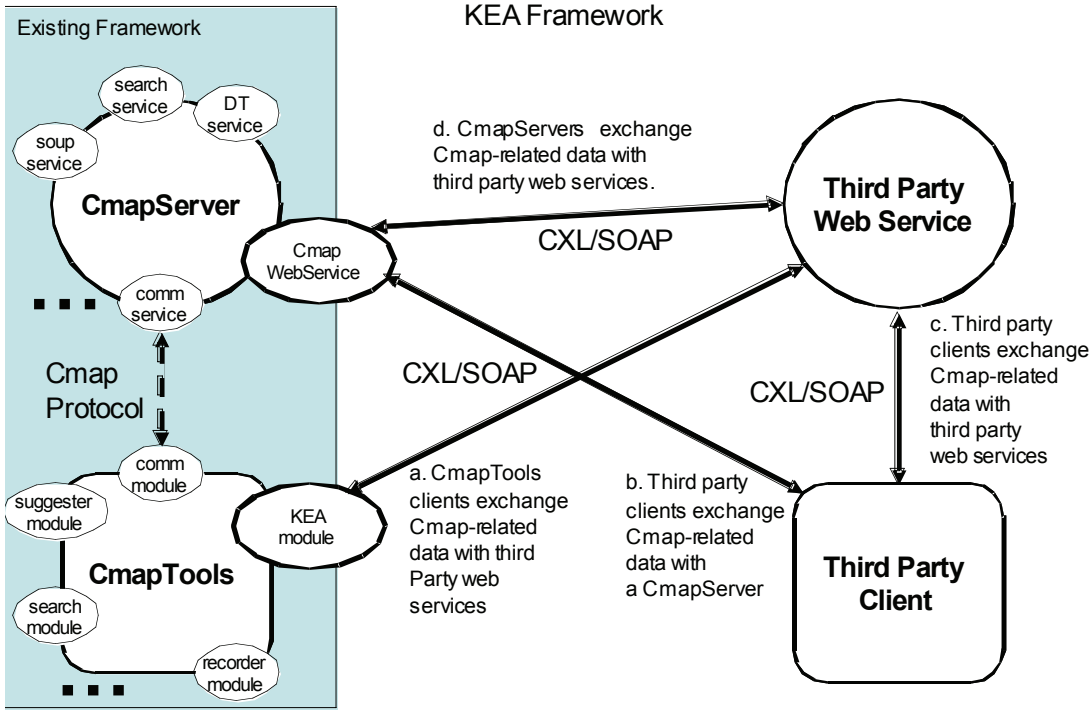


Figure 1: KEA opens the CmapTools architecture and extends the available pathways of Cmap data exchange.

reasons are beyond the scope of what we have chosen to implement in CmapTools.

To meet the needs to extend the functionality of CmapTools without continually integrating new features directly into our CmapTools software, we must go beyond the current, relatively closed architecture that is depicted by the shaded area on the left side of Figure 1. Here the data on the CmapServer is only accessible to CmapTools clients. Further, the only way to extend the application involves creating either a new 'module' in the CmapTools client or a new 'service' in the CmapServer (or both). Such development requires detailed knowledge of the inner workings of the CmapTools software.

In this paper we report on a new open architecture, KEA[1] (Knowledge Exchange Architecture), that provides the data and procedural framework to allow third party developers to design programs that interact with the CmapTools suite of programs. KEA consists of a portable, standard file format for data exchange (CXL), and a set of protocols for retrieving, storing, and manipulating Cmap information. Figure 1 illustrates the new paths of information exchange that have been made available by adapting the CmapTools client and the CmapServer to this new framework which is based on the Web Services Architecture. By adding a web services-aware module to the CmapTools client, we will enable end users to configure CmapTools to exchange Cmap related information (Cmaps, proposition lists, etc.) with third party web services designed specifically for manipulating Cmap data, as illustrated by path 'a'. By extending the functionality of the CmapServer into a web service, third party clients can now access and store CmapServer resources that were previously available only to CmapTools clients, as depicted by path 'b'. By adopting a standard open format (CXL) for Cmaps, we hope to promote the exchange of concept mapping information between third party developers, as depicted by path 'c'. And finally, the CmapServer may itself desire to exchange Cmap information with a third party web service, or a third party web service might want to request information from a CmapServer, as seen in path 'd'.

In the remainder of this paper we describe how KEA was implemented and we provide three sample client-server applications illustrating the steps we have taken toward the completion of this implementation.

2 How CmapTools Supports Open Knowledge Exchange in KEA

The open exchange of Cmaps and knowledge models requires (1) establishing open standards for the format of Cmap data and (2) defining standard protocols for client-server interaction. In both of these tasks, we have adopted the recommendations of the World Wide Web Consortium (W3C) and their emerging standards for a Web Services Architecture (Booth et al., 2004). KEA extends both the CmapTools client and the CmapServer to support such standards, thereby allowing the CmapTools client to access third party web services and allowing third party clients to access the CmapServer.

Establishing an open data format makes it possible for any client or server application to read and write the full textual, graphical, and relational content of Cmaps. We selected the "Extensible Markup Language" (XML) and defined the "Concept Mapping Extensible Language" (CXL) dialect specifically for describing the contents of Cmaps. Section 3 provides a detailed description of the CXL format. XML is a widely adopted standard maintained by the W3C (Bray et al., 2000) with multiple benefits as a representation for Cmaps. The text-based markup is independent from any programming language or operating system. It can be understood and authored by people and also parsed and generated by multiple third party software tools, making this format accessible to developers. The extensibility of the language allows for an explicit representation of concept mapping constructs (e.g. concept, linking phrase, resource link) and further enables other researchers and developers to extend this data structure without compromising compatibility.

Establishing standard interaction protocols makes it possible for any online client or server application to invoke operations on another application and receive the results. We have implemented this interoperability as web services using the Web Services Description Language (WSDL) (Chinnici et al., 2006) and the Simple Object Access Protocol (SOAP) (Gudgin et al., 2003) standards. These web services are based on XML and benefit from platform and language independence, exchanging Cmap data in the CXL format. WSDL and SOAP are emerging standards with several benefits to support the KEA interoperability goals. Web Services are self-describing through

[1] All the information needed to implement these new services is available at the CmapTools website (http://cmap.ihmc.us).

the WSDL descriptions of inputs, outputs, and bindings for each service call. This enables clients to find desired services through third party discovery mechanisms (e.g. UDDI) and to bind to such services, often very easily using one of several code generation tools that support these standards. Section 4 provides a detailed description of the web service applications we created by extending the CmapTools client and the CmapServer in order to integrate them into this more open and standardized web services framework.

3 CXL – Concept Mapping Extensible Language

CXL is a publicly available XML-based language for describing the content of Cmaps. Implementing this open and extendable representation in CmapTools is the first step toward establishing CXL as an international standard for the storage of concept maps as well as the mechanism for exchanging concept maps between programs. All concept mapping users and researchers are strongly encouraged to adopt this format, contribute to its maturation, and extend the language in their own useful and interesting ways. A brief introduction to CXL follows, in order to familiarize readers with its most basic features A full specification of the language is available at http://cmap.ihmc.us.

The CXL language is written in plain text such that users with some knowledge of the format can simply type a description of a Cmap in any text editor and CmapTools will be able to import and display the map. Similarly, any application can be enhanced to read and write files in this format. Figure 2 contains an example of a Cmap in CXL containing the proposition "Plants have Leaves".

There are four basic sections in a CXL data file. The first section defines the XML document type and any name space mappings. The second section, specified as a 'res-meta' element, contains resource level information about the Cmap such as the title, description, and author. The third section is the Cmap Data section (the second non-shaded region in Figure 2) which contains lists of concepts and linking phrases and the list of connections that link them together. The final section, Cmap Appearance, defines graphical information, such as, location, size, colors, and fonts for entities defined in the Cmap Data section. Note that the gray sections of Figure 2 are not required for non-graphical representations of a Cmap.

```
<?xml version="1.0" encoding="UTF-8"?>
<cmap xmlns="http://cmap.ihmc.us/xml/cmap.dtd"
      xmlns:dc="http://purl.org/dc/elements/1.1/">

    <res-meta>
        <dc:title>Plants</dc:title>
        <dc:description>How do plants grow?</dc:description>
    </res-meta>

    <map>
        <concept-list>
            <concept id="1" label="Plants"/>
            <concept id="2" label="Leaves"/>
        </concept-list>
        <linking-phrase-list>
            <linking-phrase id="3" label="have"/>
        </linking-phrase-list>
        <connection-list>
            <connection from-id="1" to-id="3"/>
            <connection from-id="3" to-id="2"/>
        </connection-list>

        <concept-appearance-list>
            <concept-appearance id="1" x="73" y="56"/>
            <concept-appearance id="2" x="136" y="158"/>
        </concept-appearance-list>
        <linking-phrase-appearance-list>
            <linking-phrase-appearance id="3" x="104" y="107"/>
        </linking-phrase-appearance-list>
    </map>
</cmap>
```

Figure 2: A Simple CXL Example of "Plants have Leaves"

As simple as the example in Figure 2 is, CXL can represent all the additional characteristics (links to resources, images, nested nodes, etc.) that can be added to a Cmap in CmapTools. More extensive information about the CXL format including how to specify resource links, style sheets, and propositions can be found at the CmapTools website (http://cmap.ihmc.us).

4 Implementation and Examples

As was mentioned in Section 2, we chose to implement KEA within a web services framework for achieving interoperability between CmapTools software and third party software. Doing so required that we integrate both the CmapTools client and the CmapServer into the web services architecture. To demonstrate the utility of our approach, we developed three examples of client-server applications.

Figure 3 illustrates both the specific components that we designed for our implementation and some standard components that one finds in many applications based on web services. We will first describe the standard components so that we can refer to them when describing our three example applications in detail. The standard components that play a role in all three applications are:

- The WSDL (Web Services Description Language) document. There is one WSDL document per web service. It is written in XML, and contains a description of the operations (and their inputs and outputs) provided by that web service. In order to interact with a web service, a client need only understand the interface described within the WSDL. The programming language in which the client is implemented is independent of the programming language of the web service. Their 'lingua franca' is XML.
- The XML schemas. There will normally be one or more of these that are referred to by the WSDL document for the purpose of defining the data types of each operation's inputs (to be supplied by the client) and outputs (to be returned by the web service).
- The 'stubs'. Each client application typically employs a small piece of code generated by the client developer in the language of his choice, which acts a proxy to the web service. There is typically a one-to-one relationship between the operations provided by the proxy stub and those provided by the web service. As a proxy, the stub is responsible for preparing the client request for transport to the web service, receiving the web service response, and returning the response to the client.
- The 'stub generators'. Many web service application frameworks (e.g. Axis2, JAX-WS, Microsoft .NET) provide tools for parsing a WSDL document and generating the corresponding proxy stub for the client application developer.

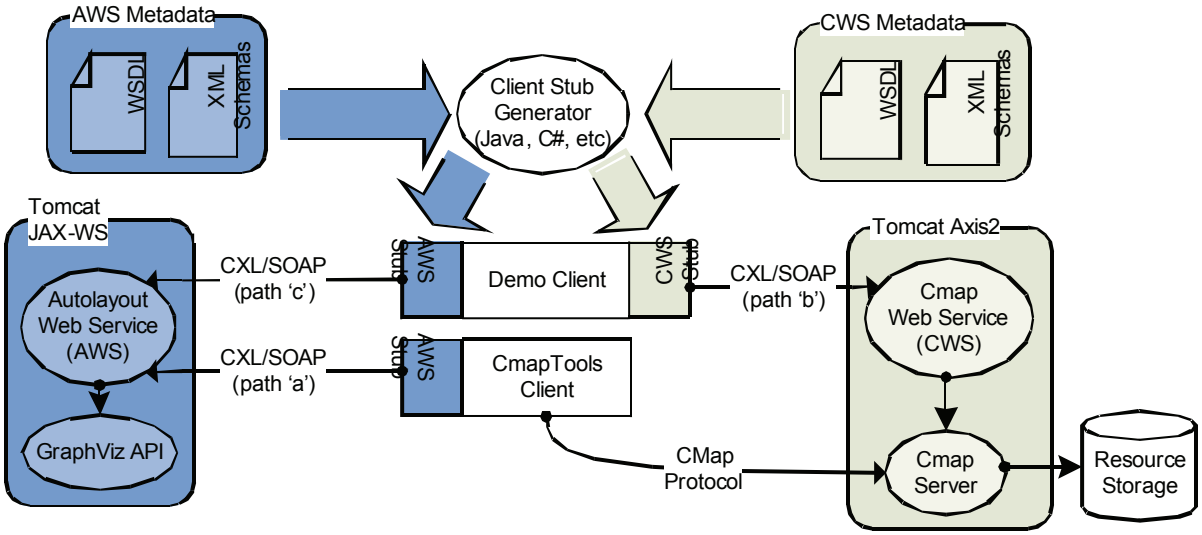


Figure 3: KEA Implementation Components.

We now point out how the three applications we developed fulfill the goals for various pathways of data exchange depicted in Figure 1. The first example will illustrate the steps that we have taken toward fulfilling the goal of implementing path 'a'. We developed a third party web service called the Autolayout Web Service (AWS), which takes a Cmap as input and returns a new Cmap that differs from the original solely in the manner in which it can be graphically displayed. This required an additional layer of functionality to be added to the CmapTools client (the AWS-interface module) that enables the client to interoperate with the AWS. The second example illustrates the implementation of path 'b'. We encapsulated a few of the most fundamental operations of the CmapServer into a web service called the Cmap Web Service. We then developed an open source reference implementation called the "Demo Client" to demonstrate how a third party client can now use web services to exchange Cmap related data with the CWS. The third and final example will show how we implemented path 'c' , namely a third party client exchanging Cmap related data with a third party web service. The various components involved in achieving the implementation of paths 'a', 'b', and 'c' are labeled as such in Figure 3. We will now proceed to explain the three applications in more detail.

Our first example, the Autolayout Web Service, is portrayed in the left hand portion of Figure 3. The AWS was designed to provide CmapTools clients with access to the latest and most advanced automated graphical layout algorithms, to enable users to better view, organize, and understand their Cmaps. Figure 4 shows an example concept map and several autolayout variants generated with AWS. Figure 4a shows a hierarchical layout, 4b a circular layout, and 4c a force-directed hierarchical layout.

We selected the GraphViz (www.graphviz.org) library of autolayout algorithms developed by AT&T (Gansner & North, 2000) as the basis for the AWS. This library is open source, written in C and C++, and is actively developed. The web services framework provides an ideal way to integrate the functionality of GraphViz with CmapTools. We abstracted the details of the programming language in which GraphViz was implemented by encapsulating the GraphViz API into the AWS. To achieve the encapsulation, we wrote a thin server-side layer that provides for bidirectional language and data translation between GraphViz (C and C++ code) and CXL. We generated a WSDL document describing the operations that we wanted to advertise to clients, and from this we generated a client stub in Java. The client stub was then encapsulated within a new CmapTools module called the

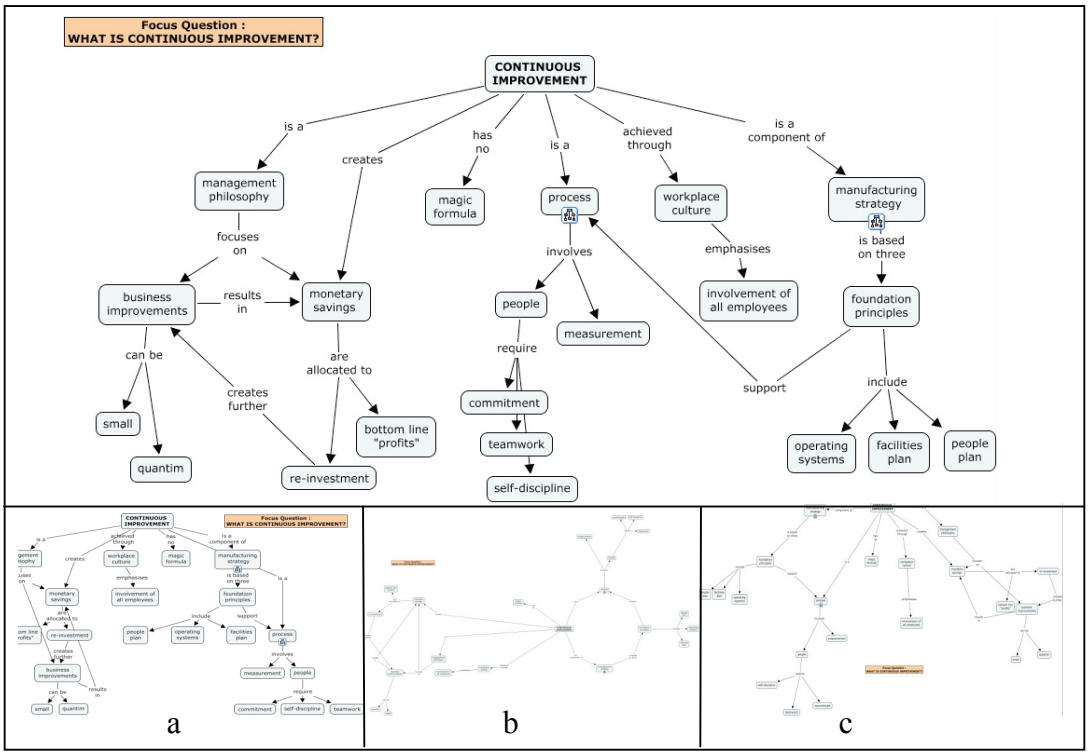


Figure 4. An example Concept Map and results from AWS.

AWS-interface Module.

The data flow between the CmapTools client and the AWS can be described as follows: The CmapTools client posts an event containing a Java-specific representation of a Cmap to the AWS-interface module. The AWS-interface module then translates this Cmap into the standardized CXL format and transports it via the SOAP protocol to the AWS. The AWS receives the CXL formatted Cmap, translates it into the GraphViz "DOT" data file format and passes it to the GraphViz API. GraphViz creates a newly laid-out Cmap as a DOT file, and the AWS translates it back into CXL. The CXL is then sent back to the client via the SOAP protocol. The AWS-interface module receives the new version of the Cmap in CXL format and translates it back into the CmapTools internal Java format.

The second example demonstrates how KEA supports Cmap-related data exchange between a third party client (the Demo Client) and the Cmap Web Service (CWS). As with the GraphViz API, the CmapServer may be viewed as an API that provides a rich set of operations for any Java developer that has access to the (proprietary) Java class definitions. Opening up this architecture entails encapsulating the CmapServer API into a web service. This was done in a manner almost identical to the means by which we encapsulated the GraphViz API. We defined a set of web service operations for the Cmap Web Service, and we designed a thin layer to direct requests and responses back and forth between the web service framework and the CmapServer API. The requests that we focused on (the operations that we wanted to export as a web service) were: (1) accessing a folder table of contents; (2) requesting a resource from the CmapServer, (3) saving a resource to the CmapServer. Once the operations were defined, we once again generated a WSDL document, accompanied by references to the appropriate XML Schemas.

We wrote the Demo Client in C# and we used the Microsoft .NET platform to generate the "CWS stub" in C#. The CWS stub is shown is shown in Figure 3 on the right hand side of the Demo Client component. The Demo Client was designed with a simple Graphical User Interface (GUI) that displays the contents of the root folder of a CmapServer to the end user. The user can then click on any other folder displayed within this hierarchy in order to see that folder's table of contents. Likewise, clicking on a resource within a folder will display the resource. In this example, the data flow would be the following: Requests made in C# are translated by the client stub into XML, which is then transported as a SOAP request to the Cmap Web Service. This service receives the request as XML and then translates it into the native Java format parseable by the CmapServer API. The CmapServer returns the requested resource (or folder table of contents) which is then translated from Java to XML by the Cmap Web Service, which in turn uses the web services framework to transport the XML data back over SOAP to the client. The client stub translates the XML back into C# and returns it to the caller. As a side note, we deployed the Axis2 web service framework along with the CmapServer into a single web application running in the VM of the Tomcat Web Server. Running all the server side code within the same Java VM made the encapsulation process a very simple one.

The third and final example demonstrates a third party client exchanging Cmaps and Cmap related data with a third party web service. In this example, the Demo Client interacts with the Autolayout Web Service. The Demo Client can retrieve a Cmap from the Cmap Web Service, send it to the Autolayout Web Service, and receive the same basic Cmap in a new graphical layout. Since the Demo Client is now also interacting with Autolayout Web Service in this example, it must employ a stub that was generated from the WSDL document specific to the Autolayout Web Service. This stub is shown on the left hand side of the Demo Client component in Figure 3.

5 Conclusions

Previously, the CmapTools architecture was relatively closed to third party developers. The only way to integrate third party code with the CmapTools client was to design a new CmapTools module, written in Java. Such a task is quite difficult, due to the prior knowledge of relevant events that the programmer must be aware of. The web services architecture described here provides a means by which previously proprietary protocols and formats may be standardized and opened up to the public, paving the way for Cmap researchers and developers worldwide to collectively create and share new and exciting capabilities in their applications.

6 References

Booth, D., Haas, H., McCabe, F, Newcomer, E., Champion, M., Ferris, C., Orchard, D. *Web Services Architecture*, W3C Working Group Note, 11 February 2004. (http://www.w3.org/TR/ws-arch/).

Bray, T., Paoli, J., Sperberg-McQueen, C.M., Maler, E., *Extensible Markup Language (XML) 1.0 (Second Edition)*, W3C Recommendation, 6 October 2000. (http://www.w3.org/TR/2000/REC-xml-20001006/).

Chinnici, R., Moreau, J., Ryman, A., Weerawarana, S., *Web Services Description Language (WSDL) Version 2.0 Part 1: Core Language,* W3C Candidate Recommendation, 27 March 2006. (http://www.w3.org/TR/wsdl20/)

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Cañas, A. J., Hill, G., Granados, A., Pérez, C., & Pérez, J. D. (2003). *The Network Architecture of CmapTools* (Technical Report No. IHMC CmapTools 2003-01). Pensacola, FL: Institute for Human and Machine Cognition.

Cañas, A. J., Hill, G., & Lott, J. (2003). *Support for Constructing Knowledge Models in CmapTools* (Technical Report No. IHMC CmapTools 2003-02). Pensacola, FL: Institute for Human and Machine Cognition.

Eskridge, T., Hayes, P., Hoffman, R., & Warren, M. (2006). Formalizing the Informal: A Confluence of Concept Mapping and the Semantic Web. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping* (Vol. 1). San Jose, Costa Rica: Universidad de Costa Rica.

Gansner, E. R., & North, S. C. (2000). An open graph visualization system and its applications to software engineering. *Software -- Practice and Experience, 30*(11), 1203-1233.

Gudgin, M., Hadley, M., Mendelsohn, N., Moreau, J., Nielsen, H.F., *SOAP Version 1.2 Part 1: Messaging Framework*, W3C Recommendation, 24 June 2003. (http://www.w3.org/TR/2003/REC-soap12-part1-20030624/)

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LA ESCRITURA Y LECTURA DE LOS MAPAS CONCEPTUALES EN LOS ALUMNOS DE EDUCACIÓN SUPERIOR

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Abstract. En este trabajo se analiza el proceso-secuencia de la escritura y lectura de los mapas conceptuales cuando estos son elaborados para la interpretación de un texto y como ayuda a la exposición de un tema. La observación realizada a dos grupos de alumnos de educación superior y de posgrado ha revelado que existe una tendencia por escribir y leer el mapa conceptual de manera secuencial de izquierda a derecha. Estas prácticas derivadas de la propia práctica de lectura alfabética (que se realiza también de izquierda derecha), desvían la interpretación y construcción jerárquica del mapa conceptual. La jerarquía del mapa conceptual se ve desplazada por secuencias narrativas de los textos sobre los cuales los alumnos elaboran el mapa conceptual. El estudio encuentra que estas prácticas son mecanismos comunes para evitar la tarea de aprender significativamente. Conocer estos mecanismos puede servir al docente para generar estrategias didácticas que estimulen un cambio de actitud para favorecer el aprendizaje significativo.

1 Planteamiento del problema

Este estudio se centra en conocer cuál es la secuencia de lectura del mapa conceptual cuando este es utilizado para la exposición de un tema. A partir de registrar la secuencia de lectura se podrá comparar:

A) El orden en que los conceptos son expuestos y leídos por los autores del mapa conceptual.
B) Si el orden de dichos conceptos se deriva de la disciplina y teoría de la que son parte.
C) Si el orden se encuentra relacionado con el orden expositivo del texto sobre el cual se ha realizado el mapa conceptual.

Los sujetos estudiados son alumnos de educación superior de niveles de licenciatura y postgrado a quienes se les pidió elaborar un mapa conceptual basado en una determinada lectura que formaba parte de un curso o seminario, para después ser expuesto en clase frente al maestro y alumnos, previo a ello se ha dado la instrucción en clase para el aprendizaje de la técnica y además se dieron guías y referencias bibliográficas de apoyo.

El interés por conocer la secuencia de *lectura y exposición* del mapa conceptual tiene implicaciones en otros aspectos de su teoría, entre ellos la representación de la jerarquía y del papel que juega la intención didáctica y narrativa en el ordenamiento de los conceptos. Otros trabajos han demostrado que el mapa conceptual puede ser leído siguiendo *rutas de lectura* (Aguilar Tamayo, 2005) y que estas dan forma a *líneas narrativas* (Aguilar Tamayo y Padilla Arroyo, 2004).

La relevancia del estudio está en reconocer que, en la práctica de escritura y lectura del mapa conceptual, el orden de los conceptos es definido por secuencias orientadas a la exposición o presentación de un tema, con mayor o menor conciencia didáctica. Aún y cuando no exista el objetivo de utilizar el mapa conceptual como apoyo para la exposición de un tema y cuando este es desarrollado a partir de un texto, se ha observado que resulta común que el orden de los conceptos reproduzca el orden expositivo del texto, esto es reforzado además por el orden narrativo-expositivo que se origina en el proceso de exposición y lectura del mapa conceptual. La técnica del mapa conceptual hace suponer que la lectura sigue la jerarquía, la cual se establece arriba hacia abajo y de esta forma se hace la lectura horizontalmente los niveles. La observación realizada ha revelado la es frecuente hacer la lectura en sentido vertical y diagonalmente (ver figura 2). Novak ya ha advertido que un uso didáctico adecuado del mapa conceptual no es aquel que reproduce en secuencias didácticas las secuencias del mapa conceptual (Novak y Gowin, 1988, p.106), pero vale la pena advertir que en el proceso de apropiación y aplicación de la técnica del mapa conceptual esta situación se presenta y dificulta la atención en *la jerarquía* y las importantes implicaciones que tiene para el aprendizaje de conceptos científicos.

2 La teoría de la representación de la jerarquía en el mapa conceptual

Por *rutas de lectura* se entiende la secuencia que se forma al momento en que el lector *lee* el mapa conceptual. Como resulta obvio, esta inicia por el concepto de mayor jerarquía y continúa de acuerdo a la jerarquía, es decir de arriba hacia abajo y de acuerdo al sentido que marque la flecha de enlace, lo que puede hacer que la lectura pueda seguir horizontalmente, que es el caso de las ligas cruzadas, o bien en sentido hacia arriba, lo que ocurre cuando se relaciona un concepto de menor jerarquía con uno que se encuentra más arriba, o en el caso de secuencias cíclicas que también es común. Un mapa conceptual puede tener varias rutas de lectura. Véase la figura 1.

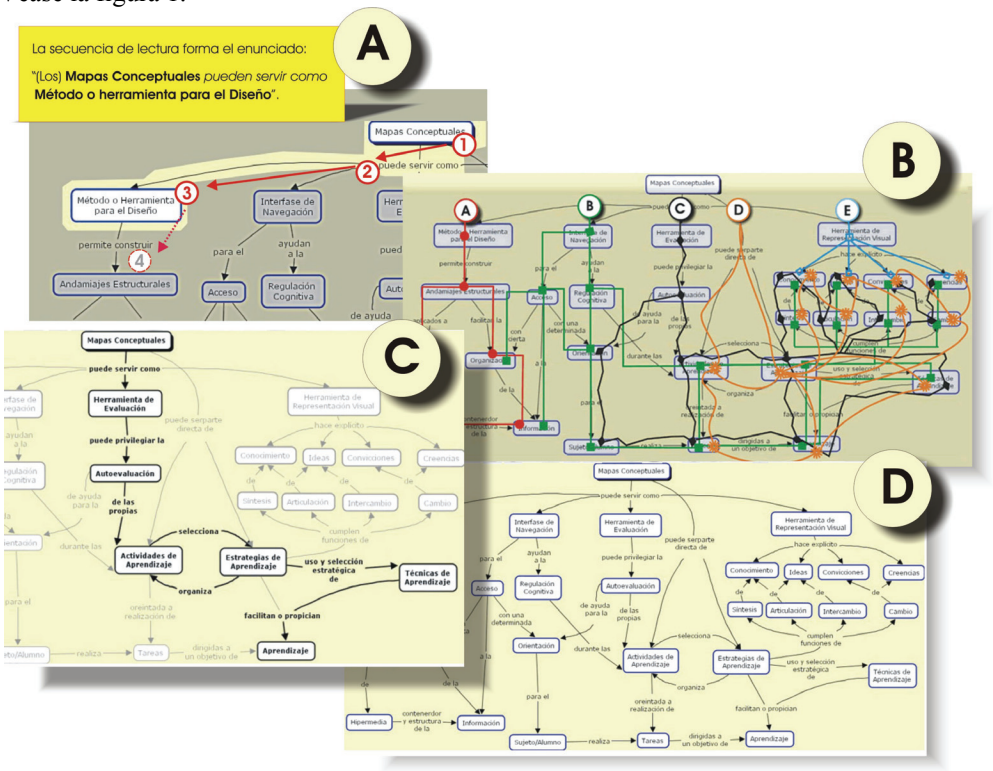


Figura 1. *Rutas de lectura o secuencias de lectura*, se forman al momento de leer el mapa conceptual y provocan una secuencia de proposiciones. En la figura 1.A se muestra la manera en que inicia la lectura de todo mapa conceptual. En 1.B se pueden observar todas las posibilidades de lectura que tiene el mapa conceptual que sirve de ejemplo (1.D). En 1.C se muestra una de las posibles rutas de lectura.

El *orden de los conceptos* es, de acuerdo a la técnica propuesta por Novak (1998; Novak y Gowin, 1988), de tipo *jerárquico.* Esto significa que los conceptos más generales ocupan niveles superiores en el plano del mapa conceptual mientras que los más particulares se encuentran en el nivel más bajo. La jerarquía depende también del contexto de relaciones entre los conceptos (Novak, 2002), es decir de la *trama* completa en la cual se relacionan los conceptos, es por esta razón que el nivel que ocupan en el plano puede variar así como su jerarquía, pues esta propiedad siempre está en relación al conjunto de conceptos que conforman el mapa conceptual.

El *origen de la jerarquía,* es decir aquello que decide el *orden de los conceptos* descrito en el párrafo anterior, lo establece el *dominio de conocimiento*. La estructura de conocimiento de una determinada disciplina que ha dado origen a conceptos explicativos con distintos grados de generalidad (Novak y Musonda, 1991, p.125), el *contexto* en el cual se enmarca el mapa conceptual (Novak, 1998, p.41; Novak y Musonda, 1991) y la *intención* de la representación, que puede tomar en consideración el dominio de conocimiento y el contexto. Todo ello puede sintetizarse en la *pregunta de enfoque* (Novak, 1998, p.283).

La representación de la *jerarquía* es importante pues a partir de ella puede observarse la *organización* del conocimiento que un sujeto tiene sobre las cosas y a partir de esto último reconocer concepciones erróneas (Novak y Musonda, 1991), esta información sirve al maestro para determinar la estrategia de ayuda al alumno

para el aprendizaje de los conceptos. La posición epistemológica de Novak sostiene que el conocimiento es construido por los humanos mediante conceptos y sus relaciones, considera también a la teoría de aprendizaje significativo de Ausubel como el marco explicativo de los procesos de asimilación del conocimiento (Novak y Musonda, 1991, p.129), de ahí al importancia de reconocer el proceso de diferenciación conceptual y proposicional que permite la construcción y aprendizaje de la jerarquía de los conceptos.

2.1 La pregunta y el problema que surge sobre la jerarquía y su representación

La técnica del mapa conceptual establece que la organización de las estructuras proposicionales deriva del concepto de mayor jerarquía y que ocupa el lugar más alto en el plano, sin embargo, el *sentido* del mapa conceptual no puede derivar únicamente de dicho concepto. En la teoría y en la observación de algunos casos, es posible concebir mapas conceptuales que inicien con un determinado concepto y que su desarrollo conduzca a la exposición de un tema o concepto distinto (Aguilar Tamayo y Padilla Arroyo, 2004), sin que ello signifique que el mapa conceptual es equivocado, aunque tal vez sí demuestre una falta en la aplicación de la técnica. En estos casos, en los que un mapa conceptual resulta coherente a la lectura, a pesar que incluya un concepto principal que no representa completamente el total de las estructuras subordinadas, la explicación se encuentra en la integración de otro elemento de significado y que dota de sentido al mapa conceptual, la mayoría de las veces de manera inconsciente e implícita; la *narración*. La unión entre los conceptos y las *secuencia de lecturas* convierten las ramificaciones del mapa conceptual en *líneas narrativas* (Aguilar Tamayo y Padilla Arroyo, 2004).

La *línea narrativa*, que es una cadena de *n* (concepto-enlace-concepto) se constituye en el acto de lectura en una *unidad de significado*, esta unidad puede hacerse más amplia si en vez del modelo: **concepto+enlace+concepto=proposición**, se pasa al modelo de: **proposición+proposición=unidad de significado.** Esta perspectiva no contradice la teoría del conocimiento de Novak (1982) que fundamenta la idea de concepto y proposición, aunque atrae una discusión respecto precisamente a la función de la proposición en el discurso científico en el campo de las ciencias naturales y en las humanas (Bruner, 2000), tema que no podrá ser abordado en este documento. Debe aclararse también que esta forma de analizar la lectura y el sentido del mapa conceptual no niega la unidad semántica y proposicional de *concepto-enlace-concepto* (Novak y Gowin, 1988) sino busca comprender esta unidad con respecto a otras y cómo, en su conjunto, mantienen una cierta *coherencia* que da sentido al *texto* que se interpreta (Aguilar Tamayo y Padilla Arroyo, 2004; Van Dijk, 1989).

A partir del análisis de diversos mapas conceptuales (Aguilar Tamayo y Padilla Arroyo, 2004) se ha podido establecer que el *orden de los conceptos* depende, además de la jerarquía, contexto y pregunta de enfoque (Novak, 1998), de una *intención narrativa del autor* del mapa conceptual (Aguilar Tamayo, 2004, , 2005; Padilla Arroyo, Aguilar Tamayo, y Cuenca Almazán, 2006, en dictamen). El *sentido del mapa conceptual,* que se construye con los elementos lingüísticos definidos por la técnica y cuyas funciones se explican por la perspectiva epistémica de Novak y la teoría del aprendizaje de Ausubel, depende también de un proceso de *interpretación* cuya unidad es más amplia que la *proposición* y que puede estudiarse a partir de las *líneas narrativas* que contiene el mapa conceptual.

El interés por la *narrativa* como forma de construir y ordenar el conocimiento y el pensamiento ha sido tratado por otros autores, uno de ellos es J. Bruner (Bruner, 1988, , 1996; , 2000). Bruner identifica dos procesos de construcción de significados, un modelo *paradigmático* cuya función es la *explicación de las cosas* y que corresponde a la forma de conocer de las ciencias naturales y físicas, y un modelo *narrativo* basado en la *interpretación* que es la manera en que se desarrolla la literatura, el conocimiento cotidiano y formas más complejas como ciertas ciencias humanas y sociales (Bruner, 1996). Este autor aclara que estos dos modos son irreductibles entre si, pero que coexisten en la experiencia humana, si bien las ciencias naturales y físicas, debido a su principio explicativo, son un proceso de constitución de *proposiciones* verificadas y verificables, el conocimiento narrativo es un proceso de construcción de significados que no llegan a ser verificables, sino *coherentes*, lo importante en todo caso no son las diferencias sino los encuentros. Bruner dice que aunque el *conocimiento científico* es explicativo y proposicional, el proceso de hacer ciencia tiene un carácter *narrativo*, los procesos creativos y de especulación científica son los productores de hipótesis, la *comprobación de ellas* es parte de un proceso distinto (Bruner, 1996, p.126). La

vida y la acción del hombre son recuperadas a partir de la construcción de relatos, ello incluye sus procesos de aprendizaje y de construcción de conocimiento.

La perspectiva de Bruner permiten resolver el problema de la jerarquía proposicional "*versus"* narrativa. La organización narrativa del mapa conceptual no anula necesariamente la jerarquía proposicional, pero queda claro también que no los fusiona, sino más bien permite la representación de ambos, la comprensión de cómo se da ese proceso quedará como un asignatura pendiente.

En la figura 2.A se muestra un esquema que representa la jerarquía conceptual y la forma en que debe hacerse la interpretación del mapa conceptual. Debido a que la jerarquía es horizontal, la interpretación debe seguir un proceso por niveles jerárquicos, sin embargo, como se muestra en 2.B, el *proceso de lectura* del mapa conceptual se efectúa, en un orden distinto, generalmente da inicio por las línea narrativa de la izquierda y una vez que esta concluye se pasa a la "siguiente". Esto es un proceso común en las exposiciones de alumnos en clase y el producto de ellos es la creación de líneas narrativas que desarrollan los contenidos del texto de manera diagonal, en ese sentido los conceptos no son presentados de acuerdo a la jerarquía.

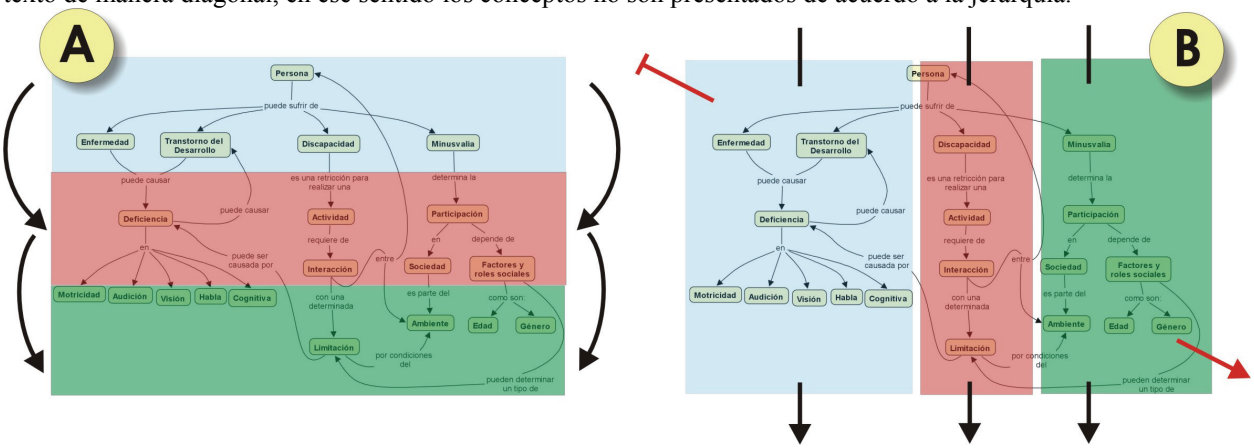


Figura 2. La técnica del mapa conceptual contempla, para la representación de la jerarquía de los conceptos, el orden espacial, esto es; entre mayor sea la generalidad del concepto más arriba del plano será ubicado y entre menor sea su generalidad será ubicado en el nivel más bajo, siendo el nivel menos inclusivo el uso de ejemplos. La *interpretación* de la *jerarquía* del mapa conceptual debe hacerse según la figura A, sin embargo los patrones de lectura son distintos, dada la práctica del sistema alfabético occidental, existe la tendencia de comenzar la lectura del mapa conceptual por el lado izquierdo (también su escritura), para continuar a la "siguiente" línea narrativa, véase la figura B. Este patrón de lectura se reproduce en la exposición de un tema apoyado por mapas conceptuales, la *narrativa* que surge de este hecho comunicativo deja de lado la *jerarquía conceptual* por un *orden narrativo*.

3 Metodología

Las observaciones se realizaron en un grupo de alumnos de licenciatura, un grupo de profesores de bachillerato durante un curso de capacitación, y un grupo de alumnos de maestría. Cada uno de los grupos presentó peculiaridades, una que resultó interesante fue notar que el grupo de alumnos de la maestría presentó más resistencia al uso de la técnica del mapa conceptual, algunos alumnos con conocimiento de otras técnicas de representación como los cuadros sinópticos y los mapas mentales, preferían presentar sus esquemas siguiendo esas otras formas de representación. A partir del diálogo con ellos fue posible advertir que se trataba de una forma de evasión para evitar la tarea de realizar el mapa conceptual. En los otros grupos se aceptó la técnica sin compararla con otras distintas.

En los tres grupos observados se dedicó una sesión para la exposición del mapa conceptual, los alumnos elaboraron un mapa conceptual y lo presentaron frente al grupo. Se decidió centrar el análisis en el grupo de maestría, la razón de esto es que uno de los autores de este trabajo mantuvo su relación docente con el grupo durante todo un semestre y el tipo de trabajo realizado requería de un mayor aprendizaje de conceptos científicos. De este grupo, el grupo de maestría, se ha seleccionado un caso para presentar. El grupo está compuesto por 10 alumnos de los cuales sólo 4 presentaron mapas conceptuales cumpliendo con las normas técnicas, los otros estudiantes presentaron esquemas híbridos respecto a los cuales se decidió no podían ser

considerados como mapa conceptual. Los análisis que se presentarán utilizando un caso fueron aplicados a los 3 mapas conceptuales restantes.

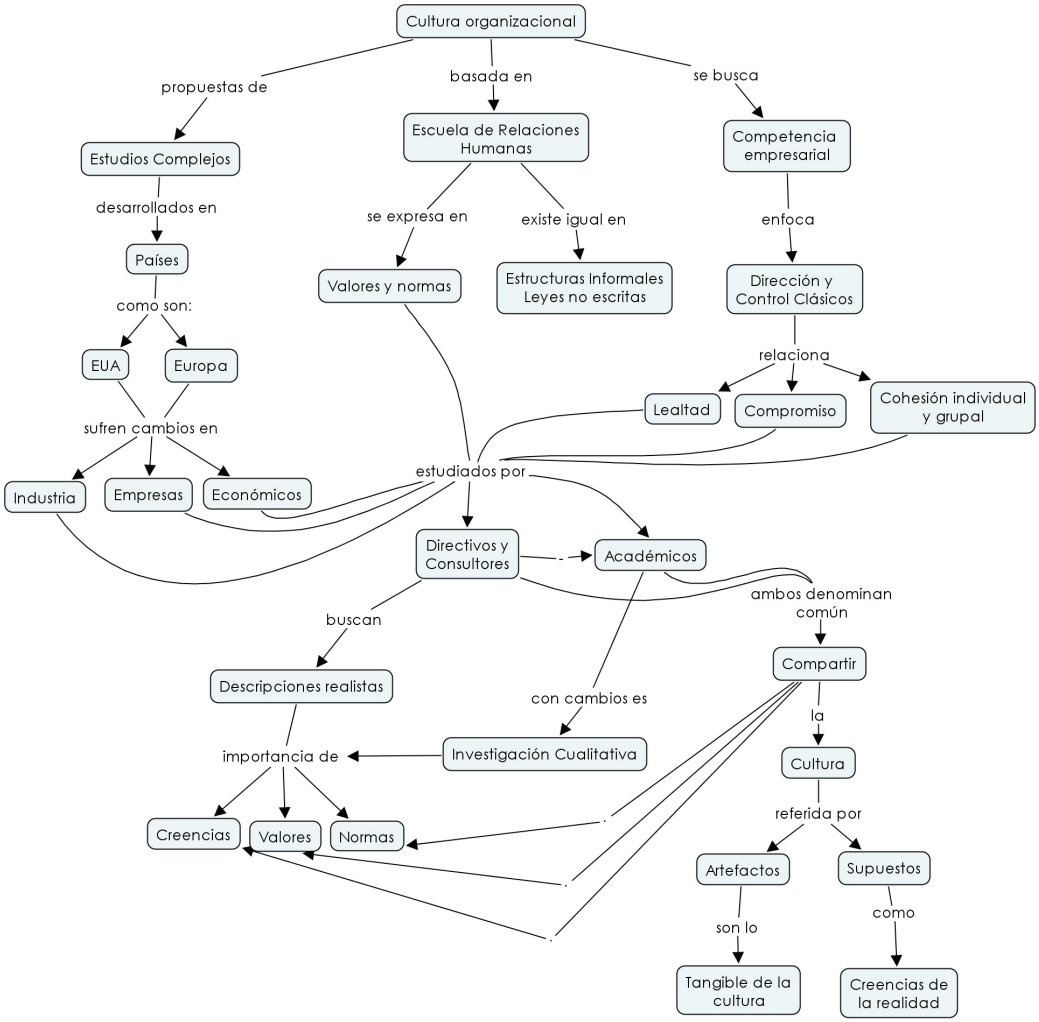


Figura 3. Mapa conceptual elaborado por un alumno de postgrado a partir de la lectura del libro de Dávila y Martínez (1999), la versión que se presenta es una trascripción del original realizado a mano, se ha respetado la disposición espacial del original y las palabras enlace faltantes son parte de las características del original. El mapa conceptual carece de una *pregunta de enfoque* y el concepto seleccionado corresponde al *tema de la unidad* que se trabaja en el momento. El desarrollo del mapa reproduce el orden de exposición del texto a partir del cual se elaboró. En la figura 4 se puede observar el orden en el que se *escribió* el mapa conceptual en el pizarrón.

Para el procedimiento del experimento se realizó una exposición sobre la elaboración de mapas conceptuales y posteriormente se ofreció a los alumnos como apoyo un artículo sobre la elaboración de mapas conceptuales. Una vez acordado que el mapa conceptual es una técnica eficaz para la interpretación de textos se pidió el análisis de un texto teórico, en este caso limitado a un capítulo (Dávila y Martínez, 1999).

Para realizar esta actividad se dejó una semana de tiempo ya que las sesiones tienen lugar una vez por semana. Se advirtió a los alumnos que el mapa conceptual serviría para entender lo que decía el texto y que sería presentado mediante una exposición en clase frente a sus compañeros. Se animó a los alumnos a realizar más mapas conceptuales. En la figura 3 se presenta el mapa conceptual desarrollado por un alumnos del grupo de maestría, los análisis siguientes se desarrollarán en base a este ejemplo. El original fue elaborado a mano y lo que se muestra es una "transcripción" utilizando *CmapTools*. Las palabras enlace que faltan tampoco estaban presentes en el original.

4 Análisis de la experiencia

De los mapas conceptuales desarrollados por los alumnos se ha tomado uno para presentar las observaciones que en la mayoría de los mapas y exposiciones se realizaron y presentando las mismas características, salvo excepciones en las cuales los alumnos realizaron un mapa conceptual sobre otra lectura, por lo que no fueron analizados; o bien porque no reunieron las características que establece la técnica y por tanto no podían ser considerados como mapas conceptuales.

En la figura 4 se presenta un esquema que representa la secuencia en que fue transcrito el mapa conceptual al pizarrón para su exposición. Esta secuencia de escritura, aunque se trate de su transcripción, reproduce la secuencia de lectura y exposición que se puede observar en la figura 5. Las secuencias que se muestran en las figuras 4 y 5 son representativas de los mapas conceptuales presentados por la mayoría de los alumnos, algunas diferencias con respecto a ellas se debieron a un mal cálculo en el espacio disponible para la escritura del mapa conceptual lo que obligó a su reelaboración y los alumnos recurrieron a otras estrategias para el uso del espacio disponible, lo que evidentemente modificó el patrón o secuencia de escritura y lectura.

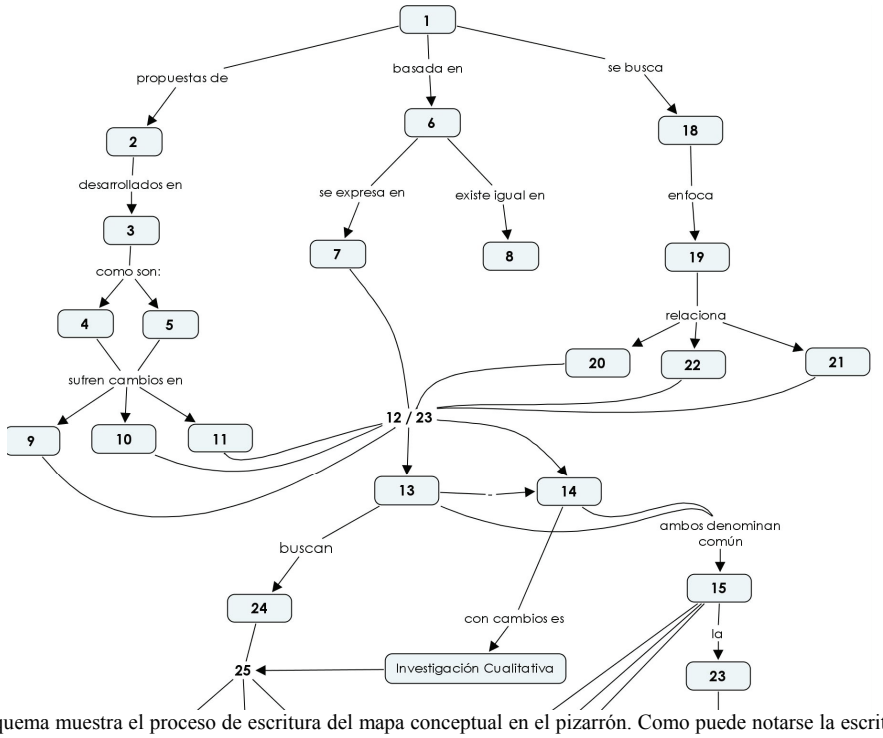


Figura 4. Este esquema muestra el proceso de escritura del mapa conceptual en el pizarrón. Como puede notarse la escritura se desarrollo de izquierda a derecha. La mayoría de los participantes comenzaron la escritura de la misma forma así como su transcripción al pizarrón. La razón de ello puede encontrarse en las prácticas occidentales de escritura de izquierda a derecha porque resulta para la mayoría de las personas organizar el espacio de los elementos gráficos y lingüísticos. Detrás de esta práctica cultural de ordenamiento espacial y alfabético, existe un orden *narrativo*. En la figura 4, se puede observar este proceso.

Se hizo un análisis comparativo entre la secuencia de los conceptos en el mapa conceptual y la secuencia de estos según aparecen en el texto que sirvió de base para la elaboración del mapa conceptual, el análisis se presenta en la figura 6. En la figura 6 se muestran grupos de conceptos designados con las letras A, B, C, D y E. Una vez agrupados los conceptos es posible observar las "uniones" entre los grupos, que en este caso ocurre mediante la liga de un concepto de un grupo a otro grupo. Esto resulta relevante por lo siguiente: Los grupos B, D y E son desarrollados secuencialmente en el texto como temas. Los conceptos al interior de los grupos son presentados de acuerdo a la secuencia de párrafos, por ejemplo, los conceptos de los grupos B y E tienen una secuencia idéntica al párrafo del texto del cual fueron tomados los conceptos, son por así decirlo, *transcripciones de los párrafos*.

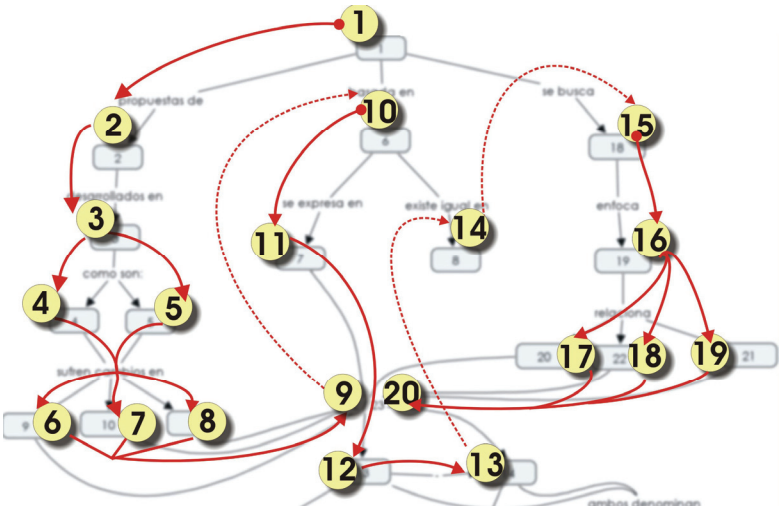


Figura 5. Secuencia de lectura y exposición del mapa conceptual. Como puede observarse el orden de exposición de los conceptos sigue en gran parte el orden de su escritura. La lectura de estas secuencias crea *líneas narrativas*, de esta forma, los contenidos del mapa conceptual son organizados de manera general en tres líneas narrativas que desembocan o se bifurcan en otras líneas secundarias. Lo relevante de esta acción es que el *orden narrativo* en la exposición y en la lectura subordina el orden jerárquico. Esto último posiblemente, se acentúa en los sujetos inexpertos en el uso del mapa conceptual, sea en su desarrollo, su aplicación o como auxiliar en la exposición de temas.

La jerarquía de los conceptos (figura 3) no corresponde a su generalidad o un orden disciplinario, sino a la secuencia con los que son mencionados en el texto sobre el cual se ha elaborado el mapa conceptual. Lo relevante no es el calificar al mapa conceptual como incorrecto o que si la técnica no se ha aplicado correctamente, aunque puede ser cierto, lo que interesa remarcar es que el trabajo de la construcción de la jerarquía es dejado de lado para representar la narrativa del texto, esto supone problemas importantes para el aprendizaje significativo de los conceptos científicos, pero también permite entender los *mecanismos de evasión* del estudiante al enfrentarse a la tarea del análisis del texto mediante la técnica del mapa conceptual. En algunos otros casos, en lecturas cuya secuencia expositiva correspondía a un método deductivo, el mapa conceptual presentó un mejor orden en la jerarquía, pero esta se derivó de la apropiación de la secuencia narrativa del texto y no de una intención del alumno por cumplir la tarea.

5 Conclusiones

Novak (1998) ha encontrado, en su experiencia en la enseñanza y aplicación de los mapas conceptuales, que los alumnos mantienen ciertas resistencias a la elaboración de los mapas conceptuales, sobre todo cuando estos alumnos tienen un dominio sobre la estrategias de aprendizaje memorísticas y éstas les han servido para alcanzar el éxito escolar. No es de extrañarse entonces que se encuentre resistencia al uso de la herramienta, lo que constituye un hallazgo, a juicio de los autores de este artículo, es el *mecanismo de evasión y simulación* que utilizan los alumnos, tanto de manera conciente como inconsciente. Algunos alumnos realizaron el mapa conceptual solicitado a partir de las primeras tres o cuatro páginas del texto. La mayoría de ellos seleccionó el concepto a trabajar del título del capítulo a leer, y la constante fue utilizar la *línea narrativa del texto* para ordenar los conceptos en el mapa conceptual utilizado.

Resulta evidente, como advierten Novak (1998) y Ausubel (2002) que entre otras cosas, para aprender significativamente se requiere por parte del alumno una *actitud para aprender significativamente*. Y aunque existen distintas estrategias para incentivar el cambio de actitud y de esa forma cambiar la forma en que se utiliza el mapa conceptual, en el contexto de la educación superior las estrategias se pueden ver más restringidas. Las formas de intervención y el mayor énfasis en la responsabilidad del alumno hacen más difícil incidir en el cambio de las *prácticas de simulación*. Existe sin embargo, la posibilidad de utilizar la autoridad académica, pero ello difícilmente cambia la actitud, sino en todo caso cambia el tipo de conducta o hace más complejas y sutiles las estrategias de resistencia y simulación.

Evidentemente existen alumnos con una actitud distinta, los límites en sus prácticas con mapas conceptuales proceden más bien de lagunas en su propia formación, sin embargo, el esfuerzo y la estrategia que supone la elaboración del mapa conceptual los llevó a apropiarse de la secuencia narrativa y así resolver el problema de cómo ordenar la jerarquía de los conceptos

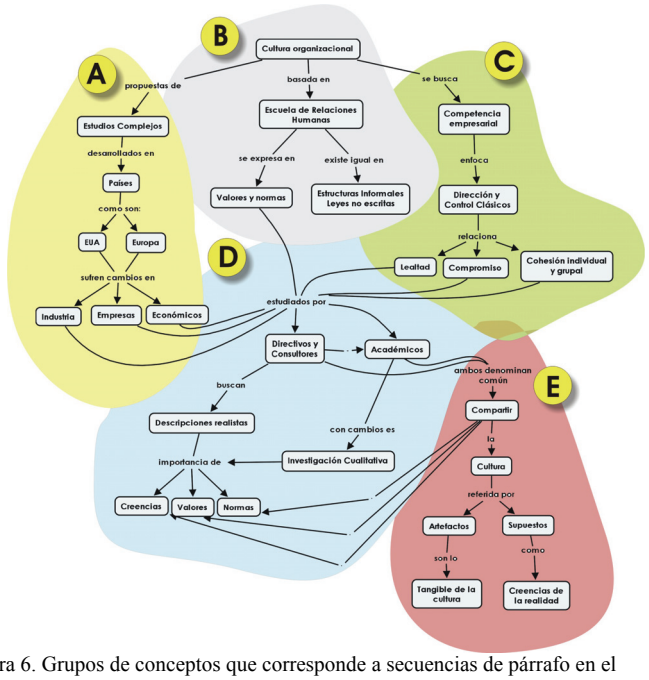


Figura 6. Grupos de conceptos que corresponde a secuencias de párrafo en el texto.

Es relevante alcanza *dominio de la técnica* del mapa conceptual, lo que ha mostrado esta investigación es que la técnica del mapa conceptual no resulta simple de entender ni de llevar a cabo. Muchos factores impiden una apropiación inmediata de la técnica, algunos como se ha dicho, son parte de la *actitud del alumno frente al conocimiento*. En los diálogos y trabajo diario con los alumnos se observa una ausencia de una formación sólida en el *conocimiento científico* y el uso del concepto para el planteamiento de problemas y el análisis de la realidad. Parece necesario entonces un uso continuo e insistente en el mapa conceptual. La investigación presentada advierte algunos mecanismos de resistencia en el aprendizaje de conceptos científico.

6 Referencias

Aguilar Tamayo, M. F. (2004). *El Mapa Conceptual: Un texto a interpretar.* Artículo presentado en First International Conference on Concept Mapping. CMC2004, Pamplona, España.

Aguilar Tamayo, M. F. (2005). *Representaciones visuales-conceptuales del conocimiento y estructura del hipermedia educativo.* Tesis no Publicada Type, Universidad Autónoma del Estado de Morelos, Cuernavaca, México.

Aguilar Tamayo, M. F., & Padilla Arroyo, A. (2004). *La Narración en los Mapas Conceptuales.* Artículo presentado en First International Conference on Concept Mapping CMC2004, Pamplona, España.

Ausubel, D. P. (2002). *Adquisición y retención del conocimiento. Una perspectiva cognitiva*. España: Paidós.

Bruner, J. (1988). *Realidad mental y mundos posibles. Los actos de la imaginación que dan sentido a la experiencia*. España: Gedisa.

Bruner, J. (1996). *The Culture of Education*. USA: Harvard University Press.

Bruner, J. (2000). *Actos de significado. Más allá de la revolución cognitiva*. España: Alianza.

Dávila, A., & Martínez, N. H. (1999). Un acercamiento crítico al concepto de cultura organizacional: Implicaciones para su estudio en organizaciones latinas. En: A. Dávila & N. H. Martínez (Eds.), *Cultura en organizaciones latinas* (pp. 17-43). México: Siglo XXi.

Novak, J. D. (1982). *Teoría y práctica de la educación*. España: Alianza.

Novak, J. D. (1998). *Conocimiento y aprendizaje. Los mapas conceptuales como herramientas facilitadoras para escuelas y empresas*. Madrid: Alianza.

Novak, J. D. (2002). Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappopriate Propositional Hierarchies Leading to Empowerment of Learners. *Science Education, 4*(86), 548-571.

Novak, J. D., & Gowin, B. (1988). *Aprendiendo a aprender*. Barcelona: Martínez Roca.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28*(1), 117-153.

Padilla Arroyo, A., Aguilar Tamayo, M. F., & Cuenca Almazán, I. (2006, en dictamen). *El mapa conceptual y la narrativa histórica.* Artículo presentado.

Van Dijk, T. A. (1989). *Estructura y funciones del discurso* (6a ed.). México: Siglo XXI.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

LA EVALUACIÓN DE MAPAS CONCEPTUALES MULTIDIMENSIONALES DE MATEMÁTICAS: ASPECTOS METODOLÓGICOS

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Resumen. En este trabajo mostraremos una investigación particular en la que exploramos la multidimensionalidad de los mapas conceptuales con la estructura probabilidad, en estudiantes para profesores de secundaria ya graduados. Mostraremos y analizaremos un caso, describiendo con detalle el objeto de la investigación y la metodología particular de investigación usada y algunos resultados derivados de una sucesión de mapas conceptuales de lápiz y papel construidos por uno de los participantes. La metodología descrita pretende aportar nuevos elementos al marco teórico que junto con otros trabajos anteriores estamos proponiendo para el uso de los mapas conceptuales en Educación Matemática.

1 Introducción

La visión multidimensional que tenemos de los mapas conceptuales de matemáticas o con contenido matemático (Huerta 2006) descansa en la noción de signo (Steinbring, 2006) y de sistema matemático de signos (Filloy, 1999; Puig 2003), en adelante SMS, y la consideración de estratos en los SMS. En relación con los planos de representación en los que puede situarse un mapa conceptual de matemáticas (MCM) asociado a cada estrato de un determinado SMS, pueden clasificarse las distintas conexiones entre nodos (conceptos), bien en un plano bien entre planos de representación, creándose sub-mapas conceptuales en un plano y entre planos de representación (Huerta, 2006). Esta visión multidimensional de los MCM permite, pues, analizarlos realizando cortes en cualquier dirección de la representación, con el objeto de obtener información sobre la representación de la estructura cognitiva de un individuo que da cuenta de una estructura de conceptos matemáticos representada en formato de mapa conceptual.

La visión multidimensional de los MCM presenta nuevos retos de corte metodológico: métodos de obtención de mapas y métodos de análisis o evaluación. En este trabajo mostraremos una investigación particular en la que exploramos la multidimensionalidad en estudiantes para profesores de secundaria ya graduados. Mostraremos con detalle el objeto de la investigación así como la metodología particular de investigación usada y los resultados derivados de una sucesión de mapas conceptuales de lápiz y papel construidos por uno de los participantes. La metodología descrita pretende aportar entonces nuevos elementos al marco teórico que estamos proponiendo (Huerta, Granell y Galán, 2004; Huerta 2006).

2 La noción de multidimensionalidad

Un MCM multidimensional (un ejemplo en la Figura 1) está constituido por (signos para) conceptos y conexiones[1] entre (signos) conceptos situados en diferentes planos de representación. Cada uno de esos planos está asociado a un estrato de un SMS con el que puede pensarse en una estructura conceptual. En nuestro caso, esta estructura es la probabilidad. Consecuentemente, las conexiones entre signos en un MCM multidimensional se producen en y entre planos de representación de manera que es posible hablar de tipos de conexiones no solo en un plano de representación sino entre planos (Huerta, 2006). Este hecho permite analizar de forma más precisa una conexión directa, por ejemplo, si se ha establecido entre signos pertenecientes a un mismo plano de representación o distintos.

El MCM multidimensional de referencia o de experto (Figuras 1 a 3), caracterizado por un SMS y sus estratos, es, en nuestro caso, fruto tanto de una fenomenología didáctica (Freudenthal, 1983) como de un análisis fenomenológico (Puig, 1997) previo de la estructura conceptual en cuestión. En la figura 1 puede verse parte del SMS que hemos considerado y de sus estratos, reconocidos por la ubicación de los signos en sucesivos planos de representación.

[1] Usaremos el término conexión en un mapa conceptual para referirnos a una relación, ya sea explícita o implícita, entre dos nodos que contienen dos signos que refieren a sendos conceptos. Hablaremos de relaciones o proposiciones entre conceptos cuando dichas conexiones se transcriben o se consideren fuera del mapa conceptual.

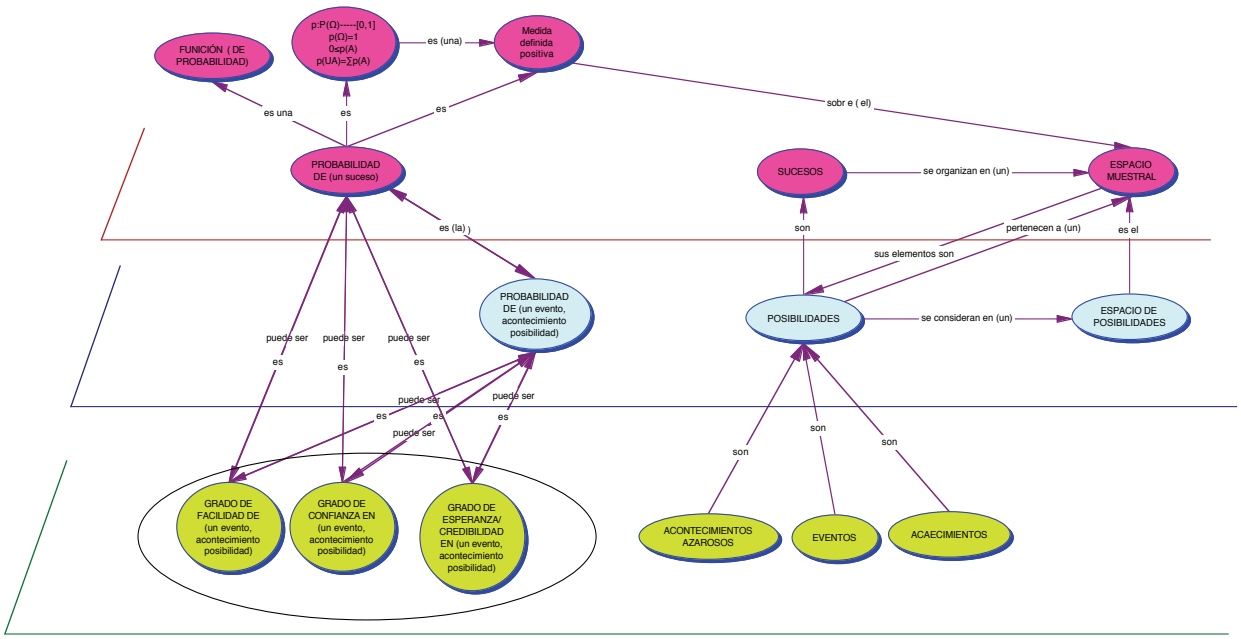
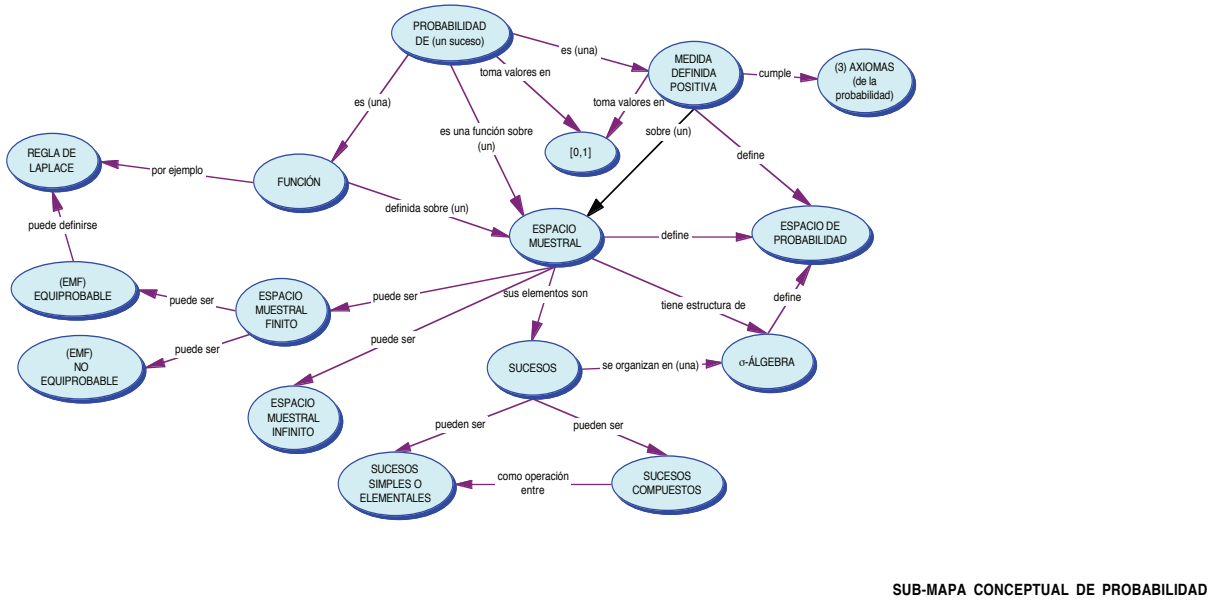


Figura 1: Mapa 1, ejemplo de representación multidimensional, aunque parcial, entre 3 planos de representación.

La consideración de la estructura matemática probabilidad es, en parte, casual. Sabemos de las vicisitudes por la que pasa habitualmente la enseñanza de la probabilidad en las escuelas primaria y secundaria, una enseñanza que puede calificarse, cuando se produce, como excesivamente formal y que usa, por tanto, un estrato más abstracto del SMS con el que se da cuenta de los problemas y de los aspectos teóricos implicados (Figura 2).



SUB-MAPA CONCEPTUAL DE PROBABILIDAD

2º NIVEL DE USO DE UN SMS.

Figura 2: Mapa 2, mapa de referencia en un plano de representación más abstracto.

Pero también hay un uso social de la probabilidad que produce, a su vez, aprendizajes espontáneos de conceptos relacionados y de los cuales hemos dado cuenta en el mapa conceptual en el mapa de la figura 3, en el que los conceptos se expresan en un estrato más concreto del SMS considerado.

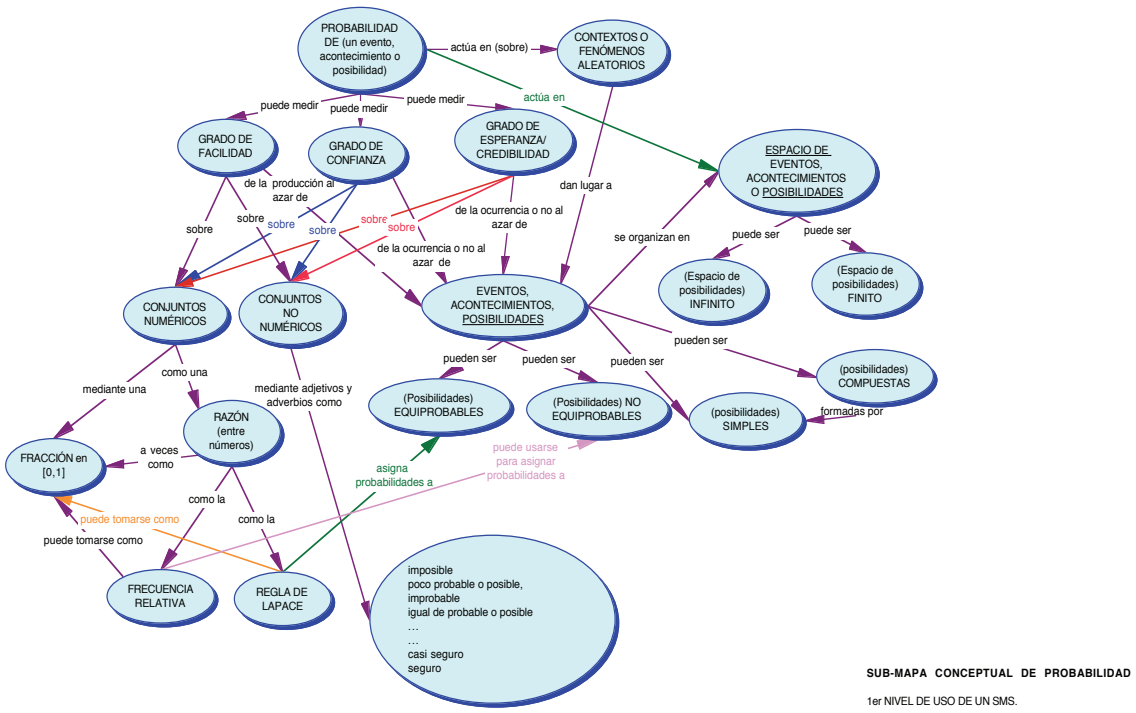


Figura 3: Mapa 3, mapa de referencia en un plano de representación más concreto.

3 Objeto de la Investigación

En esta investigación se pretende explorar la capacidad de los participantes de construir MCM multidimensionales en los supuestos siguientes: a) cuando los signos que se han de relacionar pertenecen a un estrato del SMS y b) cuando los signos que se han de relacionar pertenecen a estratos diferentes.

Teniendo presente pues los elementos teóricos propuestos en otros trabajos (Huerta, Granell y Galán, 2004; Huerta, 2006) y los párrafos precedentes, los objetivos de investigación pueden resumirse en los siguientes:

1. Analizar qué conceptos (representados por signos) se conectan con qué otros conceptos y de qué manera se conectan, cuando:
   - Las conexiones se establecen entre conceptos situados en cada uno de los dos planos de representación definidos por el mapa de referencia,
   - Las conexiones se establecen entre dos conceptos tomados cada uno en planos de representación diferentes.
2. Estudiar el proceso de construcción de los mapas conceptuales cuando se aportan sucesivamente los conceptos y los signos que refieren a esos conceptos, en un proceso continuo.

4 Método

4.1 El conjunto de conceptos proporcionados

En la Tabla 1 pueden verse los conceptos que se les proporcionó a los estudiantes organizados por fases. Tomados como conjunto, dichos conceptos constituyen un subconjunto de los conceptos que contiene el mapa de referencia, por lo que, razonablemente, el mapa conceptual que puede construirse con ellos es un sub-mapa del mapa de referencia.

Los conceptos (en mapas 2 y 3) pueden agruparse por la estructura parcial a la que responden. Así, siendo breves en esta descripción, hay un conjunto de conceptos que pretender dar cuenta de la probabilidad como una medida; otro que da cuenta de cómo se mide y del resultado de dicha medida; y un tercero que da cuenta del

contexto en el que se mide, sobre qué se mide y cómo se organiza el qué. Además de estas agrupaciones, también se distinguen por niveles de uso de los signos con los que se expresan. Por otra parte, la forma aleatoria en la que se les presentó los conceptos a los participantes en la investigación no sugerían ni agrupamientos ni subestructuras y la forma parcelada y sucesiva en la que se iban presentado respondía claramente a la posibilidad de observar el cambio conceptual y la multidimensionalidad según se iban incorporando los conceptos al mapa conceptual que iba construyéndose.

4.2 Procedimiento para la obtención de los mapas conceptuales

El procedimiento de obtención de los mapas conceptuales de los participantes puede verse en la Tabla 1, organizada por conceptos, niveles o estratos del SMS, las tareas y el grado de dirigibilidad de la misma (Ruiz-Primo, 2000), según las distintas fases del proceso.

Fase (tiempo aprox.)	**Conceptos**	**Nivel/estrato del SMS**	**Tarea**	**Grado de dirigibilidad de la Tarea**
Inicial	----------	----------	Construir un mapa conceptual	Mínimo, tanto en conceptos como en relaciones y estructura
1 (45')	Probabilidad de, Grado de, Fenómenos o contextos aleatorios, Posibilidad, Fracción, Razón, Casi Seguro, Imposible, Improbable, Seguro	Primer nivel de representación /estrato concreto	Construir un mapa conceptual con esos conceptos. Pueden aportarse otros no listados.	Bajo en conceptos y mínimo en relaciones y estructura del mapa
2 (45')	Espacio de Posibilidades, Posibilidades equiprobables, Posibilidades no equiprobables, Frecuencia relativa, Regla de Laplace.	Primer nivel de representación /estrato concreto.	Incluir en el mapa los conceptos listados, estableciendo nuevas relaciones entre todos los conceptos	Bajo en conceptos y mínimo en relaciones y estructura del mapa
3 (45')	[0,1], Axiomas, Función, Medida definida positiva, Probabilidad de, Espacio muestral, suceso	Segundo nivel de representación /estrato más abstracto	Construir un mapa con estos conceptos /Incluir en el mapa estos conceptos	Bajo en conceptos y mínimo en relaciones y estructura del mapa
4 (45')	Espacio de probabilidad, Espacio Muestral Finito, Espacio Muestral Finito Equiprobable, Espacio Muestral Finito No Equiprobable, Espacio Muestral Infinito, Suceso, Suceso Compuesto, Suceso Imposible, Suceso Seguro, Suceso Simple o Elemental, Regla de Laplace.	Segundo nivel de representación /estrato más abstracto	Incluir en el mapa los conceptos listados, estableciendo nuevas relaciones entre todos los conceptos.	Bajo en conceptos y mínimo en relaciones y estructura del mapa
5 (Hasta finalizar)	Todos los conceptos listados	Dos planos de representación/ los dos estratos del SMS	Construir un Mapa Conceptual con todos los conceptos aportados	Bajo en conceptos y mínimo en relaciones y estructura del mapa.

Tabla 1. Descripción del procedimiento de investigación por fases, conceptos y tareas.

El proceso comenzó solicitando a los participantes que elaborasen, sin ninguna instrucción previa, un mapa conceptual sobre el concepto de probabilidad (fase inicial). Acabada la tarea, se recogieron los mapas producidos, codificándolos apropiadamente para posteriores análisis. Este mapa inicial no se devolvió a los participantes en la investigación, pero sí se hizo con los sucesivos mapas que iban a construirse a continuación, pues con ello se quería comparar la competencia inicial del participante tanto con la estructura conceptual como en la elaboración de un mapa conceptual.

La observación de la multidimensionalidad se llevó a cabo solicitando de los participantes la elaboración de mapas con conceptos representables en más de un plano. Así, se inició el proceso proporcionándoles un primer conjunto de 15 conceptos pertenecientes al Mapa 3 (Figura 3), divididos en dos fases, la primera con 10 conceptos y la segunda con 5. El objeto de estas dos fases, que también se repetirá en las siguientes, fue observar la capacidad de los participantes de construir mapas conceptuales con esos 10 conceptos y si la inclusión de 5 nuevos conceptos permitía establecer nuevas conexiones con los conceptos antiguos, manteniendo las conexiones existentes o modificándolas. Cada vez que se incorporaban nuevos conceptos el estudiante debía establecer conexiones con los ya existentes, de manera que, como los conceptos nuevos pertenecen a un plano de representación diferente, ahora esas conexiones darían información sobre las estructuras conceptuales representadas en un plano y entre planos, es decir, sobre la multidimensionalidad de las conexiones.

Terminada cada fase, se fotocopiaron los mapas de los estudiantes y se codificaron para poder analizar con posterioridad la evolución de los mismos. Se devolvían los mapas originales y se proporcionaban, a continuación, un nuevo grupo de conceptos, solicitando que éstos se incorporasen al mapa en construcción. Se dio, cada vez, el tiempo necesario para que se completara la tarea de manera que los participantes pudieran construir todas las conexiones que fueran capaces de representar. El proceso total de trabajo duró un tiempo no inferior a 3 horas, sin contabilizar en él el tiempo que algunos estudiantes dedicaron a la elaboración del mapa final, trabajo que se realizó fuera de la clase.

4.3 Los estudiantes

El contexto particular en el que se desarrolló esta investigación exigió que los participantes debían de ser alumnos universitarios. En nuestro caso, fueron alumnos del Curso de Aptitud Pedagógica en Matemáticas, curso de postgrado de 3 créditos (30 horas lectivas) sobre didáctica de las matemáticas ofrecido por la Universitat de València. Estos estudiantes no necesitaron de una enseñanza previa sobre probabilidad pero sí sobre mapas conceptuales, enseñanza que se desarrolló de un modo convencional.

En total participaron en la investigación 16 estudiantes. Cada uno de éstos elaboró un mínimo de 4 mapas y un máximo de 6, entre los que se cuentan el inicial y el final. Por diferentes motivos, solamente 6 estudiantes elaboraron el 6º mapa que pretendía ser el mapa conceptual de los mapas conceptuales. El papel de los investigadores durante la sesión fue el de gestionar el proceso que se ha detallado. El tiempo que cada estudiante dedicó a la elaboración de su mapa nunca fue un obstáculo para el trabajo global ya que los tiempos que se describen anteriormente nada más son aproximados y de ninguna manera se les consideró valores de una variable de investigación.

4.4 Recogida y organización de los datos

Hemos dicho en otras ocasiones (por ejemplo en Huerta, Granell y Galán, 2004) que, desde nuestro punto de vista, los datos proporcionados por los MCM individuales requieren un tratamiento cualitativo antes que cuantitativo, si lo que nos interesa son los procesos de significación en el uso de los conceptos para el establecimiento de proposiciones matemáticas que doten de significado a los conceptos representados en el mapa conceptual. No obstante, el tratamiento cuantitativo tiene su interés para la observación de la capacidad de la estructura cognitiva de un estudiante que está construyendo un mapa conceptual de matemáticas con un determinado "tamaño", cuando el tamaño está descrito por los datos numéricos obtenidos.

La información proporcionada por los mapas conceptuales de los alumnos se tradujo a datos de naturaleza muy variada que hemos organizado en dos tipos de tablas. En unas (Tabla 2), el énfasis se puso en el recuento de los conceptos usados, distribuyendo los datos según una clasificación en pertinentes o no pertinentes a la estructura conceptual que se está representando; de primer o segundo nivel, si nos fijamos en la pertinencia del concepto y su ubicación en el plano de representación considerado en el mapa de referencia y si se proporcionan en la primera o segunda parte del proceso. También, en conceptuales (C) o no conceptuales (noC) si la no pertinencia del concepto usado tiene carácter conceptual o no. Además, se recoge también los datos macroscópicos referentes a las conexiones cuyo número total se distribuye en conexiones mencionadas (M) o no mencionadas (NoM), en función de si el usurario del mapa no sólo conecta signos sino que, además, establece claramente la conexión con una etiqueta, lo que permitirá reconocer cierto grado de competencia en la elaboración del MCM. Dichas conexiones se organizan atendiendo a su consideración de directas (D), indirectas, cruzadas (C), explícitas o implícitas (I), etc..,

aunque el análisis más minucioso de ellas se realiza mediante otro tipo de tablas (Tabla 3). En éstas, el énfasis de los datos numéricos se refieren a las conexiones representadas, atendiendo a la clasificación que de ellas hicimos en otro trabajo (Huerta, 2006). Estos datos permiten observar y analizar la capacidad de los estudiantes de establecer conexiones, tanto en un plano de representación como entre planos, distinguiendo esta capacidad en función de los tipos de conexiones. Esto nos permite ahora estudiar el grado de competencia en la elaboración del MCM, grado de competencia que puede asociarse no solo a la herramienta sino también a la capacidad de uso de los conceptos (signos) expresados en más de un estrato del SMS con el fin de establecer conexiones multidimensionales y de sus tipos.

4.5 Análisis de los datos. Objeto del análisis.

Designemos por M_{ij} un mapa conceptual construido por un participante cualquiera. Por (i, j) indiquemos el nivel o plano de representación ***i*** y el instante del proceso de obtención ***j***. Completado el proceso, están a nuestra disposición una serie de mapas conceptuales por participante sujetos a análisis posteriores. Los análisis que son entonces pertinentes tienen que ver con:

- Análisis del mapa M_{ij}
- Análisis del mapa M_{ij} en relación con el mapa $M_{i,\,(j-1)}$
- Si i>1, entonces análisis del mapa $M_{(i+1),\,j}$ en relación con el mapa M_{ij}.

El análisis de cada uno de los mapas M_{ij} tiene por objetivo analizar una estructura conceptual parcial representada por ese mapa. Este tipo de análisis es el que se corresponde con el tipo de estudio tradicional, esto es, el análisis de un mapa conceptual en un instante o en un momento dado. Pero, iniciado el proceso que describimos aquí, para cada nivel de representación ***i*** se analizan los sucesivos mapas M_{ij} para cada ***j*** en relación con los mapas $M_{i(j-1)}$, cumpliéndose entonces un doble objetivo: analizar el efecto que produce la incorporación de un nuevo conjunto de conceptos, identificados de nivel ***i*** en el mapa de referencia, en la estructura conceptual representada por el mapa M_{ij-1}, en el instante del proceso justo anterior y si este efecto supone un cambio conceptual en el participante y en qué sentido. Si el mapa de referencia considera más de un nivel de representación y el proceso investiga la capacidad de los participantes en la representación en más de un plano, entonces el análisis del mapa $M_{(i+1),\,j}$ en relación con el mapa M_{ij}, tiene por objeto analizar, entre otros, procesos de abstracción y concreción o ejemplificación de los conceptos representados en los mapas conceptuales en niveles de representación diferentes.

5 Resultados en un ejemplo.

En la Tabla 2 puede verse el número de conceptos usados por uno de los participantes, licenciado en Matemáticas, en su serie de mapas conceptuales construidos. Pero, tanto como los datos numéricos anteriores, son de interés también los aspectos cualitativos derivados de ellos. Así, son analizables, entre otros, bajo las preguntas qué y por qué: a) Conceptos usados y conceptos no usados; b) Conceptos que permanecen y conceptos que no permanecen; c) Conceptos usados que transforman su función dentro del mapa en la serie de mapas y d) Conceptos no listados que le son necesarios para dar sentido a la estructura representada.

A modo de ejemplo de lo que hemos mencionado antes, el participante, que estamos describiendo mediante la tabla 2, no usa en sus representaciones los conceptos proporcionados **Posibilidad** y **Razón**. En su lugar usa, respectivamente, **suceso aleatorio** y **fracción**. Del mapa inicial, el que llamamos mapa M_0, permanece invariante una pequeña estructura formada por el concepto **Espacio de sucesos** y su clasificación en **Discreto** y **Continuo**, resultando así que la representación de la estructura probabilidad girará en torno a esta clasificación del espacio de sucesos.

Uno de los conceptos listados de 1er nivel y en la primera fase, **grado de confianza**, se usa como etiqueta —y no como nodo— para establecer una conexión mencionada que le permite clasificar los sucesos en **Seguro**, **Casi seguro**, **Improbable** e **Imposible**. Usar el concepto de grado de confianza (y no de facilidad, credibilidad o esperanza) para clasificar los sucesos y no relacionarlo conceptualmente con el de probabilidad, indica que este participante tiene una posición subjetiva para asignar la probabilidad a dichos sucesos. Un análisis más detallado de esto último nos hace pensar que existen relaciones implícitas cuando representa en el mapa, por ejemplo, **suceso seguro** y se conecta con **p=1**, ya que expresa una relación entre lo que se mide, p(suceso seguro), y el resultado de esa medida (1), siendo el grado de confianza la base con la que se realiza esa asignación.

Nodos	Conceptos Pertinentes				Conceptos no Pertinentes			Conexiones					
	1er Nivel	2º Nivel	No listados	Total	C	NoC	Total	M	NoM	T	D	C	I
21	4	3	8	15	4	2	6	2	21	23	15	5	3

Nodos	Conceptos Pertinentes						Conceptos no Pertinentes			Conexiones					
	1er Nivel		2º Nivel		NL	Total	C	NoC	Total	M	No M	Total	D	C	I
15	8	1	1	0	6	16	0	0	0	1	15	16	9	6	1
19	6	4	2	1	10	23	0	0	0	3	18	21	12	7	4
25	5	4	7	0	12	28	0	1	1	7	25	32	16	7	3
28	5	4	7	9	9	34	0	1	1	15	32	47	20	16	3
21,75	6	3,25	4,25	2,5	9,25	25,25	0	0,5	0,5	6,5	22,5	29	14,25	9	2,75

Tabla 2. Análisis cuantitativo de la serie de 5 mapas conceptuales de uno de los participantes en la investigación.

El concepto de probabilidad evoluciona desde su relación con fracción (no como razón), pasando por su relación con la frecuencia relativa y la regla de Laplace, estableciéndose una serie de conexiones implícitas entre estos tres conceptos: probabilidad, frecuencia relativa y regla de Laplace. Mientras esto ocurre el concepto de fracción desaparece también. Cuando se introducen aspectos relacionados con la definición formal de probabilidad, se producen dos sub-mapas no relacionados entre sí, al menos explícitamente. De una parte, se mantienen los conceptos anteriores constituyendo una pequeña estructura y de otra se crea una nueva, aparentemente independiente, con los conceptos medida, función, axiomas etc. No estamos seguros de que el participante relacionase, tampoco implícitamente, ambos sub-mapas.

Si el énfasis, hasta ahora, lo hemos puesto en los conceptos y su función dentro del mapa, también las conexiones y sus tipos tienen especial interés en los procesos de significación. En la tabla 3 pueden verse la distribución del número de conexiones según las distintas clases de conexiones identificadas y su evolución a lo largo del proceso. Como era de esperar, ninguna de las conexiones establecidas se clasificó como indirecta. Establecer este tipo de conexiones no parece que sea tan natural como lo pueda ser establecer las conexiones directas o cruzadas, independientemente del plano de representación. Esto puede decirse, al menos, en el contexto particular en el que se ha investigado. Este hecho permite hacernos una idea de hasta qué punto los sub-mapas que integran el mapa global representan realmente sub-estructuras conceptuales, ya que las conexiones indirectas, por su parte, aportan al mapa algo más que simplemente una cadena de conceptos distribuidos de alguna manera y conectados directamente según están dispuestos en la cadena. Mientras que éstas dan lugar a proposiciones que podemos llamar naturales, aquéllas dan lugar a proposiciones que contienen al menos a otras dos deducibles de sendas conexiones directas. Por otro lado, las conexiones cruzadas aportan proposiciones entre conceptos situados en sub-mapas distintos, lo que ciertamente da lugar, junto con las otras, a una verdadera estructura conceptual.

	Conexiones totales				Directas				Indirectas				Cruzadas				Implícitas			
Del plano i al plano j	1.1	1.2	2.1	2.2	1.1	1.2	2.1	2.2	1.1	1.2	2.1	2.2	1.1	1.2	2.1	2.2	1.1	1.2	2.1	2.2
1→1	0	2	2	2	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
1→2	6	6	5	5	1	1	1	1	0	0	0	0	4	4	4	4	1	1	0	0
2→1	6	7	7	6	5	4	4	4	0	0	0	0	1	3	3	2	0	0	0	0
2→2	6	10	14	26	3	6	10	14	0	0	0	0	1	2	2	10	2	2	2	2
Totales	18	25	28	39	9	12	16	20	0	0	0	0	6	10	9	16	3	4	3	3

Tabla 3. Análisis cuantitativo de las conexiones establecidas en una serie de 4 mapas conceptuales.

6 Conclusiones

La metodología de obtención de los mapas conceptuales de los participantes que hemos presentado no solo permite explorar un mapa conceptual en un instante dado sino que permite, además, analizar la evolución de la representación de sus estructuras cognitivas mediante una serie de mapas conceptuales. Los análisis puntuales y comparados de dichos mapas permiten explorar en los estudiantes la multidimensionalidad de la representación y obtener conclusiones sobre el aprendizaje de una determinada estructura conceptual, cuando ésta se expresa mediante signos que pueden situarse en más de un estrato del sistema matemático de signos en el que es posible su representación.

Aunque siempre hemos abogado por los análisis cualitativos de los mapas conceptuales, con esta metodología de investigación es posible considerar un buen número de datos cuantitativos que pueden dar cuenta, esta vez, del tamaño de la estructura cognitiva del participante. Estos datos cuantitativos determinan, de una parte, el volumen de conceptos con los que el participante es capaz de armar una estructura cuando los representa como nodos en el mapa conceptual; de otra, la capacidad de establecer relaciones o proposiciones entre esos conceptos mediante la cantidad y la clasificación de las conexiones establecidas en los mapas; además de la complejidad de la estructura representada tanto por el número de conceptos —nodos— y su ubicación en diferentes planos de representación como por las conexiones entre ellos. Tamaño de la estructura cognitiva del participante que está así relacionada con el volumen de conceptos y de relaciones y con la complejidad en el uso de los signos para la representación de los conceptos, generalmente como nodos, y las conexiones entre nodos.

El aprendizaje se interpreta cualitativamente mejor si se considera la multidimensionalidad en los MCM. Esta interpretación está basada, por ejemplo, en una visión del aprendizaje de las matemáticas que contempla a los signos situados en un plano de representación superior (Mapa 2) como medios de organización de los fenómenos descritos por los signos situados en un plano de representación inferior (Mapa 3).

Lo que aquí hemos ofrecido como ejemplo debería estar sujeto a nuevas investigaciones con otras estructuras conceptuales y otros participantes. El objetivo de este conjunto de investigaciones debería ser aportar a la comunidad de investigadores en Educación Matemática una herramienta que teniendo su origen en otros campos su potencial en el nuestro está por precisar. Potencial del que hemos referido aquí un ejemplo y que está en relación con los datos que puede aportar y que tiene como finalidad aportar elementos para construir un marco teórico que permita (re)considerar la evaluación de los estudiante mediante mapas conceptuales de matemáticas o con contenido matemático.

7 Referencias

Filloy, E., 1999, *Aspectos teóricos del Algebra Educativa*. Grupo Editorial Iberoamericana: México D.F.

Freudenthal, H., 1983, *Didactical Phenomenology of Mathematical Structures*. Dordrecht, Reidel.

Huerta, M. P., 2006, Las conexiones entre conceptos en un mapa conceptual multidimensional de matemáticas. (Documento no publicado).

Huerta, M.P.; Galán, E., Granell, R, 2004, *Concept Maps in Mathematics Education: A Possible Framework for Students' Assessment*, en http://www.icme-organisers.dk/tsg27

Puig, L., 1997, Análisis fenomenológico, en Rico, L. (coord.), 1997, *La Educación Matemática en la Enseñanza Secundaria*, Cuadernos de formación del profesorado, nº 12, ICE Universitat de Barcelona, pp. 61-94. (Horsori: Barcelona).

Puig, L., 2003, Signos, Textos y Sistemas Matemáticos de Signos, en Filloy, E. (ed), *Matemática Educativa: Aspectos de la Investigación Actual*. Fondo de Cultura Económica / CINVESTAV: México D.F., pp. 174-186.

Ruiz-Primo, M., 2000, El uso de mapas conceptuales como instrumentos de evaluación del aprovechamiento en ciencias: lo que sabemos hasta ahora. *Revista Electrónica de Investigación Educativa*, vol. 2, (1). Read on November 30, 2001 at http://redie.ens.uabc.mx/vol2no1/contenido-ruizpri.html.

Steinbring, H., 2006, What Makes a Sign a Mathematical Sign? – An Epistemological Perspective on Mathematical Interaction, *Educational Studies in Mathematics* (on line).

LA PREGUNTA PEDAGÓGICA COMO INSTRUMENTO DE MEDIACIÓN EN LA ELABORACIÓN DE MAPAS CONCEPTUALES

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Abstract. La presente ponencia constituye una propuesta metodológica, para el uso de preguntas pedagógicas en la elaboración de Mapas Conceptuales, dentro de un contexto dialéctico. Esta propuesta surge como resultado de dos insumos, primero, el trabajo con estudiantes a nivel universitario, particularmente en la formación de docentes para el Educación Preescolar de la Universidad de Costa Rica; segundo, la investigación realizada con dos grupos de niños y niñas en edad preescolar, de instituciones públicas, en la ciudad de Cartago, Costa Rica.

1 Introducción

El abordaje de las preguntas pedagógicas y su papel en la elaboración de mapas conceptuales ha sido un tema metodológico prácticamente ausente en la diversa literatura sobre mapas. ¿Cómo conducir un proceso de construcción de mapas conceptuales? ¿Cuál es el papel docente que corresponde? Estas son dos de las preguntas que dan origen a la presente ponencia. Para quien suscribe, las preguntas pedagógicas han sido tema de estudio permanente en la formación de docentes de Educación Preescolar, con el propósito de provocar un aprendizaje significativo y un efecto relevante (Chacón, 2004)

Es hasta hace algunos años, con la incorporación de mapas conceptuales en los cursos, que la temática de preguntas pedagógicas, como instrumento de mediación, retoma un interés particular. Utilizar preguntas pertinentes en el proceso de construcción de mapas conceptuales permite, en buena medida, mostrar, comprender y atender el proceso de pensamiento que se produce en las personas al momento construir conceptualizaciones.

De acuerdo con lo anterior, esta ponencia reafirma que los mapas conceptuales en un contexto educativo, corresponden esencialmente a herramientas de proceso, que posteriormente tienen como resultado una producción final, no necesariamente acabada. Se reafirma además, que una las funciones docentes estriba en atender, de manera pertinente, la producción de cada estudiante de acuerdo a su propio estilo de aprendizaje o pensamiento.

2 ¿Cuáles contextos prácticos sirven de insumos a esta propuesta?

Dos tipos de contexto, constituyen el marco práctico en el cual se ha utilizado y probado la pregunta pedagógica como instrumento de mediación para la elaboración de Mapas Conceptuales: el contexto universitario y el contexto en Educación Superior.

2.1 El contexto universitario

Quien suscribe cuenta con 25 años de laborar en la formación de docentes para la Educación Preescolar en la Universidad de Costa Rica, en los ámbitos de didáctica del desarrollo lingüístico-cognitivo y de investigación. Los cursos de Artes del Lenguaje I y II, así como los Seminarios de Graduación, constituyen los ambientes que facilitan la comprensión de cómo se produce el aprendizaje en adultos y cómo se establece una mediación didáctica. En los últimos años se han incorporado, en estos cursos, los mapas conceptuales como herramientas para la construcción del aprendizaje, la sistematización de lo aprendido y la organización conceptual, a partir de lo cual se valora desde una visión de proceso, los logros de las estudiantes.

En dicho proceso las estudiantes han sido capaces de reelaborar sus mapas conceptuales y establecer reflexiones metacognitivas que las llevan a tomar conciencia sobre su propio aprendizaje. Sin embargo estos procesos no se producen se han producido por propia iniciativa, necesariamente se ha dado la intervención de mi persona como docente. La utilización de preguntas de diverso nivel han provocado la toma de conciencia, el desequilibrio, y la acomodación del pensamiento (Piaget, 1975). La intervención docente ha permitido la búsqueda de respuestas propias y la elaboración de interrogantes que conducen a la reflexión, ya sea de manera individual o colectiva. Ejemplos de estas intervenciones se ofrecen en el apartado 4.

2.2 El contexto en Educación Preescolar

Una investigación desarrollada durante el año 2005 y parte del 2006, con dos grupos preescolares, de entre los 4 y 6 años de edad, corresponde al segundo contexto que aporta a la presente propuesta. Esta investigación fue atendida por un grupo de seis estudiantes de Licenciatura en Educación Preescolar, bajo la dirección de quien suscribe. Para tal efecto el objetivo principal estuvo centrado en comprender el proceso de organización del pensamiento en el nivel preescolar, para lo cual se diseñó una propuesta metodología de elaboración de mapas conceptuales en el nivel preescolar. Una vez aplicada la metodología se concretaron tres resultados:

- Dos mapas conceptuales, sobre las temáticas del "*conejo*" y la "*mariposa*", en un proceso que requirió, en uno los casos 10 sesiones y en el otro 12 sesiones.
- Un análisis del proceso de organización del pensamiento y su representación.
- Una versión final de Propuesta Metodológica para Elaborar Mapas Conceptuales en el Nivel Preescolar.

Es este contexto de Educación Preescolar el que ofrece insumos para comprender la utilización de preguntas pedagógicas como mediación en la construcción de mapas conceptuales con niños y niñas. Ejemplos de esta intervención se ofrecen en el apartado 4.

3 ¿Cuál es el marco conceptual de referencia que sustenta esta propuesta?

3.1 Enfoque comunicativo dialéctico

Este enfoque promueve una comunicación respetuosa entre las personas que comparten un espacio educativo. El término dialéctica es utilizado para señalar la capacidad para organizar un ambiente en el cual el diálogo se utiliza para provocar un intercambio de ideas que lleven al desarrollo del pensamiento. Para el contexto escolar, Tourtet (1987:1) señala que *"La dialéctica es el despertar del espíritu mediante preguntas hábilmente conducidas y en especial, por las preguntas que plantean los propios niños, preguntas que les interesan, cuyo eco en ellos es profundo y en consecuencia la necesidad de corresponder a su desarrollo efectivo y a las aspiraciones de su crecimiento mental"*.

3.2 Las preguntas pedagógicas, más que simples preguntas

Cualquier pregunta corresponde a un problema que debe ser resuelto y que necesita, por tanto, de una o varias respuestas, ya sean simples o complejas. (Chacón, 2000).

Dentro de un contexto comunicativo común, el planteamiento de preguntas emerge para responder básicamente a una necesidad comunicativa o informativa, sin una conciencia explícita de su intencionalidad. Por otra parte, dentro de un contexto educativo caracterizado por la dialéctica, el planteamiento de preguntas pedagógicas, conduce a una toma de conciencia de las elaboraciones cognitivas que se producen, ya sean éstas simples o complejas, particularmente divergentes. Es así que "*La actividad de preguntar se inserta en una pedagogía que asume el paralelismo del pensamiento y del lenguaje manifestado en la relación comunicativa…"* Valera y Madriz (2006:6).

Del tal manera que, encontramos en la pregunta pedagógica una poderosa estrategia cognoscitiva, que de acuerdo con Poggioli (2006), conlleva, por una parte, a la elaboración verbal para la adquisición del conocimiento y por otro, al desarrollo del pensamiento divergente al procurarse la solución de problemas. Para ello es necesario suscitar buenas preguntas, oportunas, de nivel bastante elevado, de tal manera que provoquen entusiasmo por dar una respuesta, sin embargo no tan difíciles que desanimen y se renuncie a la búsqueda (Tourtet, 1986). Es así que en un ambiente educativo dialéctico, es propio que se produzca entre docentes y estudiantes, el intercambio de interrogantes y la colaboración sobre posibles respuestas, para lo cual se ponen de manifiesto las diversas capacidades intelectuales y emotivas.

Aunque con poca frecuencia se destacan las capacidades emotivas en el proceso de aprendizaje, valga señalar que especialmente las capacidades de conmoción, curiosidad y para sorprenderse, colaboran en procesos de desequilibio y equilibrio (Ausubel, Novak, Hanesian, 1987; Chacón, 2004). De tal manera que dentro de un entorno de aprendizaje significativo, la pregunta pedagógica debe generar, entre otras, aquellas capacidades emotivas que favorezcan el proceso de anclaje entre subsunsores y nueva información.

3.3 El papel mediador del o la docente

Hablar del papel mediador docente nos lleva necesariamente a comprender las implicaciones pedagógicas de la Teoría del Aprendizaje Significativo (Ausubel, 1989), de la intervención en la zona de desarrollo potencial, según Vigotsky (1963) y de la intervención entre el sujeto y el objeto, según Piaget (Badilla, Chacón y Jinesta, 1995). Todos coincidentes en una intervención pedagógica pertinente, por parte del adulto.

En el entendido de que un mapa conceptual corresponde a un proceso y no sólo a un resultado, se debe tener presente que el o la docente en su papel de "mediador" es quien gestiona el acercamiento entre la pregunta generadora inicial y las posibles respuestas. Una de sus funciones será favorecer el proceso continuo entre desequilibrio y equilibrio cognitivo, según lo define Piaget (1975); de aquí la variedad en el tipo de preguntas por utilizar.

En este caso el o la docente interviene de manera conciente para plantear preguntas y provocar en otros el planteamiento de preguntas propias. *"Formular-se buenas y pertinentes preguntas no es una tarea fácil, bien se sabe, pero es imprescindible como actividad de enseñanza y de aprendizaje. Un aspecto importante de una intervención pedagógica adecuada reside justamente en la formulación de preguntas adecuadas en el momento oportuno. Las preguntas ayudan a fortalecer los intercambios y la participación activa en las conversaciones en el aula"* Valera y Madriz (2006:6). Los mismos autores indican la necesitad de contar con conocimiento sobre el contexto, así nos dicen que "*Una pregunta tiene sentido en un determinado contexto. El preguntar correcto exige disponer de cierto conocimiento, y también el saber lo que se pregunta, a quién o a qué se le pregunta, cómo debe formularse, y en el contexto del saber desde el que se realiza la pregunta (Valera y Madriz. 2006:7).*

Esta razones justifican el necesario soporte de conocimiento didáctico en la formulación de preguntas por parte del docente: conocimiento sobre capacidades cognitivas relacionadas al desarrollo humano, el tipo de preguntas para el desarrollo cognitivo, el empleo del lenguaje, y las capacidades cognitivo-comunicativas que se deseen suscitar.

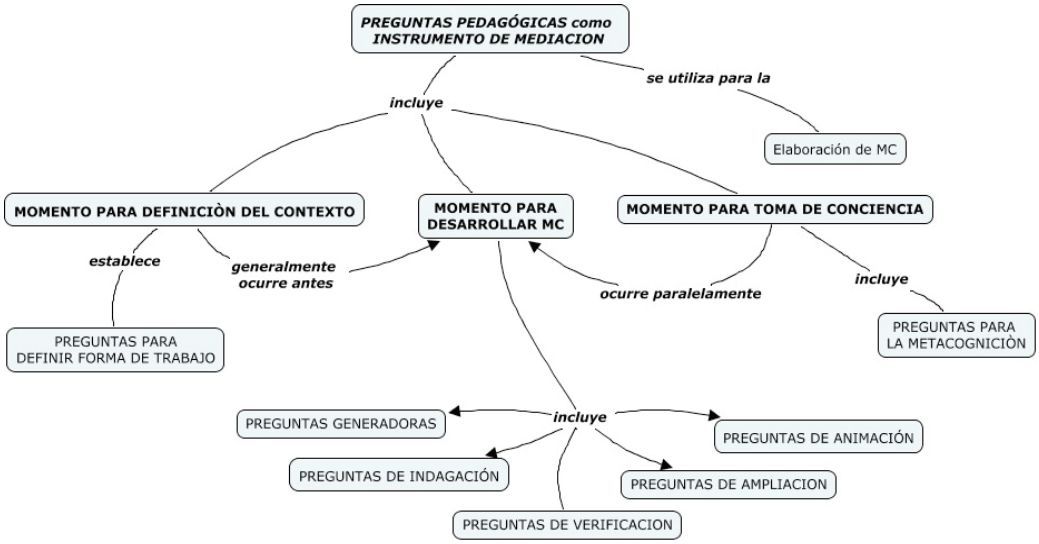
4 Las preguntas pedagógicas: una propuesta de mediación para la construcción de mapas conceptuales

Teniendo como insumos las experiencias realizadas, tanto a nivel preescolar como universitario, en cuanto al empleo de preguntas pedagógicas para la construcción de mapas conceptuales, así como la base conceptual ya descrita, se proponen tres momentos enlazados al uso de la pregunta pedagógica: momento para definición del contexto, momento para el desarrollo del mapa conceptual y momento para la toma de conciencia. En el siguiente mapa conceptual se resume la propuesta.

A continuación se describen los tres momentos y el tipo de preguntas que les corresponden.

4.1 Momento para la definición del contexto

En este momento se plantea el proceso metodológico sobre el cual se aborda la construcción del mapas, en este sentido es importante abordar una serie de interrogantes que ayudan a aclarar el proceso metodológico a seguir según el contexto que se ocupa, por ejemplo:



Mapa de Elaboración propia

- ¿Por qué deseamos abordar el problema planteado?
- ¿Por qué el uso de mapas conceptuales para resolver el problema?
- ¿quienes participan en su elaboración?
- ¿Con qué hacemos el mapa conceptual?
- ¿Dónde hacemos el mapa conceptual?
- ¿Cómo vamos a representar los conceptos?
- ¿Dónde encontramos información?, etc.

Estas preguntas, como todo proceso complejo, se proponen al inicio, pero también se intercalan durante el desarrollo del mapa conceptual para ir adaptando el proceso metodológico. Algunas personas pensarían que estas preguntas sólo competen al docente mismo, sin embargo, podríamos sorprendernos cuando éstas se comparten con niños y niñas. En un entorno de preescolar, se ha dado la experiencia de compartir la toma de decisiones para establecer dónde, con qué hacer el mapa, como representar los conceptos, cómo hacer los enlaces. Adicionalmente, en un entorno de educación superior, es posible efectuar un planteamiento conjunto de las interrogantes ante el grupo de estudiantes. En ocasiones las preguntas se devuelven al docente, un estudiante podría señalar: ¿Por qué tenemos que hacer un mapa conceptual y no un resumen?

4.2 Momento para el desarrollo del mapa conceptual

El desarrollo propiamente dicho del Mapa Conceptual, genera varios tipos de preguntas que regularmente son abordadas por los y las docentes, pero que también son expresadas por los mismos estudiantes, en un ambiente fluido de colaboración.

4.2.1 Pregunta generadora del mapa

Para clarificar la pregunta inicial que da origen al Mapa Conceptual. Cuáles son..., cómo es..., para qué...

4.2.2 Preguntas de indagación

Estas se plantean para establecer lo que se sabe inicialmente respecto al asunto a tratar. Una condición para que se de el aprendizaje significativo establece la necesidad de que el aprendiz cuente con un conocimiento previo relevante (Novak y Cañas, 2006). Para este caso, preguntas tales como: dónde, qué cosa, quien, etc., proporcionan información sobre este conocimiento previo. En un ambiente grupal debe tenerse cuidado de la participación de todas las personas. A continuación se presentan varios ejemplos, algunos en el entorno de educación preescolar, otros en educación universitaria, ambos entornos descritos en el apartado 2.

Ejemplo de preguntas en educación preescolar

- ¿Quién conoce los aviones?
- ¿Cómo son los aviones?
- ¿Qué hay en un avión?
- ¿Para qué sirven?
- ¿Dónde están?

- ¿Quiénes usan los aviones?
- ¿Quién los ha visto?
- ¿Quién ha viajado en avión?, etc, etc.

Ejemplo de preguntas en educación superior

- ¿Qué saben sobre métodos de lectura?
- ¿Ha escuchado sobre alguna teoría para el aprendizaje de la lectura?
- ¿Quién recuerda cómo aprendió a leer?
- ¿Cuál es diferencia entre métodos de lectura?

Ejemplo de diálogo en educación preescolar:

Maestra: -¿Qué nos dirá este mapa?-
Mariam: -donde ir-
Todos los niños y niñas localizaban los mapas acercándose y señalándolos.
Maestra: -¿Todos son iguales?-
Mariam: -No, porque hay algunos mapas que guían-
Maestra: - ¿Qué es esto?- (señalando las líneas trazadas en el mapa)
Niños: - Son los caminos-
- Son para encontrar-
Maestra: -¿Qué encontramos?-
Niños: -Todo-
- Las cosas que se perdieron-
- Son para encontrar tesoros-
Maestra: - ¿Servirá sólo para buscar tesoros?

4.2.3 Preguntas de verificación

Los mapas conceptuales son fuertes herramientas que permiten identificar el conocimiento relevante que poseen los aprendices (Novak y Cañas, 2006). Identificar este conocimiento permite al docente intervenir para que aquellos puedan verificar, reorientar, reflexionar sobre sus propias ideas. Las preguntas de verificación se establecen entonces para señalar si las proposiciones del mapa conceptual son ciertas o no. Si son coherentes y claras. Algunas de estas preguntas pueden ser:

- ¿Esto que dice aquí, es cierto?
- ¿Estás seguro de que la situación es así?
- ¿Qué opina.....(un compañero) al respecto?
-

De igual manera que en el punto anterior, el ejemplo que a continuación se presenta corresponde al entorno de educación universitaria, ya descrito en el apartado 2.

Docente: -Carolina fíjese en esta proposición, usted dice que la lateralidad es un concepto aprendido, ¿qué es lo usted quiere decir con esto?-
Estudiante:- Bueno, que los conceptos de izquierda y derecha se aprenden-.
Docente: -Entonces ¿lateralidad y concepto de izquierda y derecha son lo mismo? ¿La lateralidad se puede enseñar?-.
Estudiante: -No, la lateralidad no se enseña. ¿Pero cuál es la diferencia-?
Docente: -¿Por qué la lateralidad no se puede enseñar? Recuerde lo analizado en clase, las actividades que hicimo-.
Estudiante: -Cierto, la lateralidad se define neurológicamente-.

4.2.4 Preguntas de ampliación

Según Novak y Cañas (2006), la capacidad del aprendiz para establecer nuevos conectores entre conceptos o dominios de un mismo mapa, incluso con otros mapas, facilita el pensamiento creativo. Novak y Cañas hacen ver llegar a un aprendizaje significativo creatividad se hace necesario un compromiso emocional para integrar nuevo conocimiento con uno ya existente. Por tanto las preguntas de ampliación se formulan para determinar si hace falta información o ampliación de conceptos; también para establecer mayores relaciones entre conceptos, ya sea a nivel vertical, pero especialmente a nivel horizontal. Los ejemplos que a continuación se presentan corresponden a los entornos de construcción de mapas conceptuales ya descritos en el apartado 2.

Ejemplo 1, diálogo en educación universitaria:

Docente: -Bueno, si la lateralidad se define neurológicamente, entonces ¿Qué pasa con los conceptos de izquierda y derecha? ¿Cuál es la relación entre lateralidad y conceptos de izquierda y derecha?-.
Estudiante: -Es que los conceptos de izquierda y derecha se aprenden, una maestra puede enseñarlos, pero para eso los niños deben tener su lateralidad definida-.
Docente:- Claro que si, esa es una relación clara. Pero además de una lateralidad definida, ¿de qué debe estar conciente el niño?-.
Estudiante: -De su cuerpo-.
Docente: -Si claro, pero particularmente conciente de qué, si su cuerpo es en principio simétrico.
Estudiante: ya, ya entendí, ya recuerdo, se necesita una conciencia bilateral, por eso es importante que los bebés gateen-.
Docente: -Eso es, entonces ¿que nuevas proposiciones podrías elaborar-.
Estudiante: Podrían ser: -"Lateralidad Definida es necesaria para aprender Conceptos de Izquierda y Derecha" "Acción de Gatear favorece la Conciencia Bilateral,
"Conciencia Bilateral es condición para comprender Conceptos de Izquierda y Derecha-".

Ejemplo 2, diálogo en educación preescolar:

Maestra: -¿El mapa sólo sirve para encontrar cosas?-.
Todos: - No, no -
Maestra: -Por ejemplo, si yo estoy aquí y quiero ir donde está el árbol, ¿puedo hacer un mapa para llegar?-.
Todos: -Si-



Gloria y grupo de preescolar. Cartago. Costa Rica.

Ejemplo 3, diálogo en educación preescolar:

A partir de la propuesta ofrecida por un niño:
"las mariposas son insectos", surgió la pregunta:
¿los insectos son animales? Las respuestas fueron:
- *No porque tienen alas.*
- *Si fueran insectos, los animales nacerían en capullo.*
- *No, porque los animales son grandes como elefantes y los insectos son pequeños como hormigas.*
- *Los insectos vuelan y los animales no.*

Se aprovechó una paloma que andaba caminando por el lugar y se les preguntó: -¿ustedes creen que esa paloma es un animal?-. Respuesta:
- *Si la paloma es una animal.*

Maestra: -¿Y la paloma vuela?-. Las respuestas fueron:
- *Si vuela pero es un animal porque es grande.*
- *Las mariposas mueren rápido y los animales duran más tiempo*
- *El perro es una animal porque crece*

Maestra: -¿Los insectos son seres vivos?-
- *Si porque nacen del capullo, crecen, se reproducen y después mueren.*
- *La hormiga reina es grande pero no es un animal, porque es hormiga.*

Maestra: - ¿Cuáles pueden ser otros animales?-
- *El león, el perro, el tigre, el gato, la jirafa.*

Maestra: -El ratón es pequeño ¿el ratón es un animal?
- *Si el ratón es un animal.*

Maestra: -¿Y las serpientes que son?-
- *Las serpientes no son animales, son reptiles.*

Posteriormente se solicitó a niños y niñas que investigaran si los insectos son animales o no lo son.

4.2.5 Preguntas de animación

Novak y Cañas (2006) hacen ver que la creación de un nuevo conocimiento, es un proceso de construcción que envuelve tanto nuestro conocimiento como nuestras emociones, ello conduce a la creación de nuevas representaciones del pensamiento.

Esta es una fuerte razón para pretender animar a niños, niñas y adultos, a que produzcan sus propias representaciones. Cuando logramos representar lo que pensamos es cuando tomamos conciencia de lo que creemos o sabemos. Es por ello que las preguntas de animación son de carácter afectivo, con ellas se pretende animar a la producción de ideas y su representación. Los ejemplos que a continuación se presentan corresponden a los entornos de construcción de mapas conceptuales ya descritos en el apartado 2.

Ejemplo de diálogo en educación preescolar

> *Cuando se le pidió a Abril que dibujara la segunda palabra importante de la idea "El conejo come lechuga", al levantar la mano dijo: - Yo no sé hacer la lechuga-.*
> *Maestra: -¿De dónde sale la lechuga?-*
> *Después de un silencio la maestra formula otra pregunta: -¿La lechuga nacerá en un árbol-. Nuevamente nadie responde, por lo que la maestra sugiere que alguien le cuente a Abril ¿Cómo es una lechuga?*
> *Dolly: -Es una pelotita con hojas-.*
> *Abril: - Es que por mi casa hay lechugas sembradas -.*
> *Maestra: ¿Abril y es un árbol de lechuga lo que está sembrado?*
> *Abril: -Noooo-*
> *Maestra:- ¿Cómo es?-*
> *Abril: -Es que está sembrado bajo, en la tierra-.*
> *Maestra: -Tratá de dibujarlo-.*

De este tipo de preguntas, las que mayor conflicto cognitivo generan, son las de verificación y de ampliación, por cuanto en determinado momento las preguntas de ampliación y verificación se mezclan. Su atención se centra en las proposiciones mismas, en la lectura alineal, pero también en la lectura general del mapa.

4.3 Momento para la toma de conciencia: la metacognición.

La toma de conciencia se produce al momento de desarrollar el mapa y al concluir el mismo. Las preguntas de se dirigen a la metacognición, la cual se refiere a una toma de conciencia sobre la manera en que se construyen los conceptos y la toma la información, ofreciendo para ello explicaciones: estoy describiendo, estoy deduciendo, estoy estableciendo una relación, estoy aplicando, estoy suponiendo. Es decir la autorregulación, para comprender, analizar, explorar, aplicar, planear (Patry, 2006).

En este momento el o la docente debe favorecer esta toma de conciencia, formulando preguntas que lleven al estudiante a ofrecer esas explicaciones.

Ejemplo 1, diálogo en educación universitaria

> *Estudiante: - Profesora, he dedicado mucho tiempo a este mapa-*
> *Docente: - ¿Ha tenido alguna dificultad? -*
> *Estudiante: - Si, la interpretación, tener que hacer mis propias ideas.-*
> *Docente: - ¿Y por qué siente que eso le ha costado?-*
> *Estudiante: -No estoy acostumbrada a pensar, poco me han pedido que analice, ni en el colegio.-*

Ejemplo 2, diálogo en educación universitaria

> *Docente: Tatiana, ¿qué relación puede establecer entre el concepto de Lectura convencional y Simbolización, que usted puso en su mapa?. Elabore una proposición con esos dos conceptos.*
> *Estudiante: "La simbolización es necesaria para la lectura convencional"*
> *Docente: Tatiana, ¿cómo se llama esa capacidad que usted acaba de utilizar?*
> *Estudiante: acabo de interpretar y relacionar*

5 Consideraciones finales

La propuesta de las preguntas pedagógicas como instrumento de mediación en la construcción de mapas conceptuales, corresponde a una propuesta que como tal puede ser llevada a la práctica en diversos niveles educativos. En este artículo se han presentado ejemplos reales de dos contextos educativos distanciados, la educación preescolar y la educación universitaria. En ambos casos el papel mediador del docente es el mismo, la profundidad del proceso varía, según el interés y los propósitos que se persigan.

Para aquellas personas que deseen incursionar en una educación mediadora, será fundamental su propia formación como docente, en cuanto a:

- Asumir una actitud de humildad, para comprender que no lo sabe todo.
- Asumir una actitud de respeto y aceptación de diversas opiniones y respuestas.
- Respetar diferentes estilos de pensamiento y conocimiento que se generan en su entorno educativo.
- Desarrollar capacidades comunicativas.
- Conocer sobre desarrollo cognoscitivo y cómo se produce el aprendizaje.
- Concebirse como aprendiz.

Las preguntas pedagógicas, por sí, constituyen una fuerte estrategia cognoscitiva, pero enlazadas a la construcción de mapas conceptuales, transcienden para producir y organizar el pensamiento divergente y la metacognición, para favorecer la creatividad.

Referencias

Ausubel, D., Novak, J., Hanesian, H., (1987). Psicología Educativa. Un punto de vista cognoscitivo. 2ª. España: Editorial Trillas.

Chacón, S., (2004). "Entre Conector y Conector, un Pensamiento". En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra, Vol 1, pp.143-150.

Chacon, S., (2000). Las preguntas pedagógicas. Notas de Clase. Curso FD-0176 Artes del Lenguaje II. Universidad de Costa Rica.

Novak, J. (1998). conocimiento y Aprendizaje. Los mapas conceptuales como herramientas facilitadoras para Escuelas y empresas. Versión Celina González. España: Alianza Editorial.

Novak, J. D., & Cañas, A. J. (2006). *The Theory Underlying Concept Maps and How to Construct Them* (Technical Report No. IHMC CmapTools 2006-01). Pensacola, FL: Florida Institute for Human and Machine Cognition, (Consulta: 2006, Abril 8). Disponible en: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm.

Patry, J., (2004). "Efects of short term training in concep-mapping on the developmet of metacognition". En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra. Vol 1, Págs. 503-510.

Rodríguez, M.L (2004). "La teoría del Aprendizaje Significativo". En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra. Vol 1, Págs.535-544.

Piaget, J. (1975) Psicología y Epistemología.

Poggioli, L. Estrategias Cognoscitivas: una perspectiva teórica. Disponible en http://200.74.229.60/poggioli/poggio19.htm. (Consulta: 2006: Febrero 5).

Tourtet, Lise. (1987) Lenguaje y pensamiento preescolar. España: Narcea S.A.

Valera, G., Madriz, G. Las preguntas pedagógicas en la enseñanza de las ciencias humanas. Un estudio ecológico de aula universitaria. Revista Iberoamericana de Educación. Disponible en http://www.campus-oei.org/revista/deloslectores/034Madriz.PDF (Consulta: 2006, Febrero 5).

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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LA UTILIZACIÓN DE MAPAS CONCEPTUALES COMO ESTRATEGIA DIDÁCTICA PARA LA CONSTRUCCIÓN Y ORGANIZACIÓN DEL PENSAMIENTO EN EDAD PREESCOLAR

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Abstract. A continuación se exponen los resultados y conclusiones de una investigación, basada en la implementación de una propuesta metodológica innovadora para la construcción de Mapas Conceptuales en edad preescolar. Esta experiencia tuvo lugar en dos jardines Infantiles estatales de la ciudad de Cartago, Costa Rica. La población infantil la conformó un grupo de niños y niñas con edades entre los cuatro años y seis meses a los cinco años y seis meses (Interactivo II) y otro grupo con edades entre los cinco años y seis meses a seis años y seis meses (Transición). Dicha investigación evidencia un proceso de construcción de pensamiento individual y colaborativo por parte del niño y de la niña. Ofrece además, fundamentos teóricos que respaldan los resultados e interpretaciones acerca de la construcción y organización del pensamiento infantil, a partir de las construcciones verbales y gráficas de los grupos participantes. La experiencia permitió la construcción de dos mapas conceptuales sobre temas propuestos y seleccionados por los niños y las niñas, los cuales reflejan la funcionalidad del mapa conceptual como estrategia didáctica, generadora de Aprendizaje Significativo y el papel del equipo investigador como agente mediador en el proceso de construcción y organización de conocimientos de los niños y las niñas.

1 Introducción

La evolución de las posibilidades cognitivas de los niños y las niñas en la actualidad demanda la apertura de nuevas e innovadoras metodologías en el campo educativo. En este sentido la construcción de Mapas Conceptuales como una estrategia didáctica, posibilita un cambio educativo que favorece la construcción y organización del pensamiento de los niños y niñas desde edades tempranas, partiendo de sus estructuras mentales como bien lo explica Piaget (1967) y de acuerdo a sus características, experiencias, necesidades e intereses. La construcción de Mapas Conceptuales permite el Aprendizaje Significativo dentro de un proceso colaborativo y protagonizado por los alumnos y alumnas conjuntamente con la mediación docente.

2 Problema que sustenta la investigación

¿Cuáles son los procedimientos didácticos más pertinentes en el uso de mapas conceptuales que favorezcan la organización y construcción del pensamiento infantil, según sus intereses?

3 Referencias Conceptuales

El referente conceptual contiene diferentes posiciones y pensamientos de importantes autores; a saber: Novak, Piaget, Vygotsky, Ausubel, Huck y Lowenfeld

3.1 Mapas Conceptuales según Novak

Para Novak (1998), el Mapa Conceptual corresponde a una estrategia que permite representar el conocimiento, es entonces, una poderosa herramienta para facilitar el aprendizaje, así como un instrumento de evaluación. Según Novak y Gowin (1988) el Mapa Conceptual es la representación de un determinado esquema conceptual: "…los mapas conceptuales constituyen una representación explícita y manifiesta de los conceptos y proposiciones que posee un persona". El Mapa Conceptual posee estructura jerárquica y esta estructurado por proposiciones; estas a su vez corresponden a la unión lógica de dos conceptos, por medio de palabras de enlace y conectores.

3.2 Desarrollo Humano según Vygotsky

Para hablar sobre desarrollo humano Vygotsky (citado por Riviere, 1994), considera en primera instancia al ser humano como un ser capaz de construir su propio conocimiento de forma activa, en contraposición a la primera ésta diferencia "Desarrollo" y "Aprendizaje", señala para ello que, aunque el aprendizaje no es fundamental para el

desarrollo, el desarrollo es condición para que exista aprendizaje. El proceso de aprendizaje que vivencia cada individuo según Vygotsky (citado por Harry 2003) genera en él un Nivel de Desarrollo Actual (capacidad individual para la resolución de problemas.) el cual se enriquece con la Zona de Desarrollo Potencial (espacio de conocimientos que podría obtener el individuo en interacción con otros) y esta a su vez permite alcanzar el Nivel de Desarrollo Potencial (capacidad colaborativa para la resolución de problemas) el cual implica una transformación cualitativa.

3.3 Aprendizaje Significativo según Ausubel

Para David P. Ausubel (1918, citado en la Enciclopedia de la Psicopedagogía) el aprendizaje significativo se define como el proceso que involucra una interacción entre la información nueva y la estructura específica del conocimiento que posee el aprendiz. Este proceso genera a) un significado a la nueva idea, b) reducción de la posibilidad de ser olvidada, al relacionarlas con ideas afines y c) accesibilidad de la información.

3.4 Pensamiento Constructivista según estudios de Piaget

El pensamiento infantil según Piaget (citado por Ginsburg s.a) evoluciona a través de cuatro etapas con ordenación invariable, con límites aproximados de edad y se dan a lo largo de un proceso continuo y gradual. Las etapas son las siguientes:

- Etapa sensorio-motora: se presenta entre los 0 y 2 años de edad. Se caracteriza por ser una etapa donde se promueve el aprendizaje por medio de experiencias y la herencia.
- Etapa pre-operacional: entre los 2 y 7 años de edad. Esta etapa se caracteriza por la presencia del egocentrismo, el cual se centra en el punto de vista propio y no en el de los demás. Además es aquí, donde aparece el simbolismo, el cual consiste en formar símbolos mentales que sustituyen los acontecimientos y/o objetos; y el lenguaje es utilizado como medio de socialización y medio de comunicación.
- Etapa de operaciones concretas: se presenta entre los 7 y 11 años de edad. En esta etapa desaparece el egocentrismo y se da una mayor capacidad verbal. El niño y la niña poseen mayor capacidad en su pensamiento, en términos del todo y sus partes.
- Etapa de operaciones formales: se da de los 11 años en adelante. Se caracteriza por desarrollarse una mayor capacidad de razonamiento y análisis. Además, se da un equilibrio del pensamiento.

Piaget (1967) destaca que las personas desarrollamos estructuras (unidades que conforman el intelecto y que varían en función de la edad) las diferencias individuales y la experiencias intelectuales básicas, las cuales se evidencian durante las primeras tres etapas del desarrollo y estructuras intelectuales de orden superior, que se presentan en la etapa de operaciones formales y que requieren de una mayor capacidad de razonamiento.

3.5 Desarrollo gráfico según Lowenfeld

En cuanto al desarrollo gráfico se destaca la clasificación que realiza Lowenfeld (1972) sobre las etapas del desarrollo entre las que se encuentran la etapa pre-esquemática que abarca aproximadamente las edades entre los 4 a los 7 años, caracterizada por la vinculación de los pensamientos con el mundo real dentro de un marco emotivo que parte de las experiencias personales; otra de las etapas expuestas es la esquemática que abarca las edades entre los 7 a los 10 años aproximadamente, en ella los niños y las niñas muestran mayor grado de conciencia de la forma y la realidad, por lo que sus representaciones contiene muchos detalles que describen la realidad que perciben, la emotividad es aún mayor por la riqueza de sus experiencias, poseen mejor dominio del espacio y capacidad para relacionar los elementos de sus dibujos.

3.6 Pregunta pedagógica según Huck

Huck (1976) establece una clasificación según el tipo de pregunta, esta es: pregunta de memoria, que solicita el recuerdo de algo vivenciado directa o indirectamente, de comprensión la cual amerita una representación original, de interpretación, esta requiere de la connotación de la persona que responde; la pregunta de aplicación, la cual busca dar solución a un problema planteado; la pregunta de análisis que implica un nivel de razonamiento y las preguntas de síntesis y evaluación las cuales ameritan un mayor grado de raciocinio. El mismo autor expone que las preguntas pedagógicas deben tener finalidad y desarrollar el pensamiento divergente.

Finalmente las preguntas, pedagógicas fundamento de la intervención docente, son definidas por Silvia Chacón (2005) como "… las preguntas intencionadas, que pretenden promover el desarrollo de un amplio rango de capacidades cognitivas").

4 Procedimiento metodológico

Esta investigación tiene su origen en la propuesta de investigación de la MEd. Silvia Chacón Ramírez, profesora de la Universidad de Costa Rica y desarrollada por un grupo de seis estudiantes que optan por el grado de Licenciatura en Educación Preescolar en dicha universidad.

El equipo investigador se dividió en dos subgrupos, uno trabajó con una población de diez niñas y niños y otro con once niños y niñas con edades anteriormente mencionadas. La población infantil participante en la investigación se eligió al azar. Anterior a este proceso se realizó un periodo exploratorio con otras poblaciones y a partir de un análisis de la información obtenida en este periodo, se elaboró una "Propuesta Metodológica Inicial para la construcción de Mapas Conceptuales", ésta fue implementada con las poblaciones infantiles seleccionadas en el trabajo de campo.

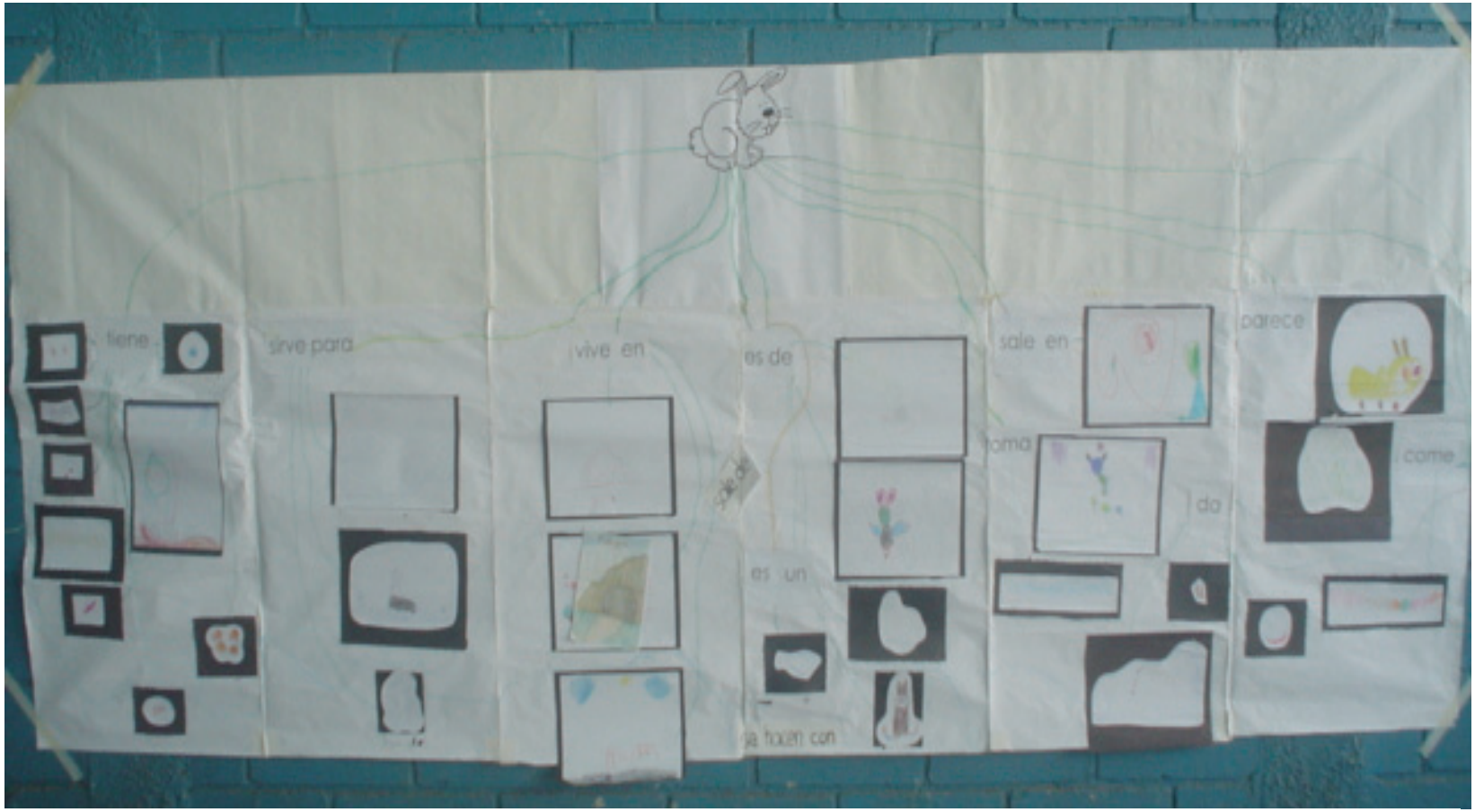
La propuesta inicial elaborada está constituida por cuatro etapas de ejecución, que por efectos de espacio no se detallan, éstas son:

- Primera etapa: Exploración del concepto de mapa, por medio de actividades introductorias concernientes al concepto de mapa, con las cuales los niños y las niñas asimilan dicho concepto. Entre ellas están: a) realizar recorridos en su cuerpo de un punto de salida a un punto de llegada, utilizando un dedo, b) Dibujar un mapa de su propia aula.
- Segunda etapa: Formulación de ideas, sobre un tema antes propuesto por los niños y las niñas. El docente como mediador formula preguntas generadoras que incentivan la participación activa del grupo.
- Tercera etapa: Representación y organización de las proposiciones, las ideas son transformadas en proposiciones, las cuales son escritas de manera visible al grupo; se identifica en ellas los conceptos y palabras de enlace, posteriormente los conceptos son representados gráficamente y éstos sustituyen los conceptos escritos en las proposiciones y se establecen los conectores.
- Cuarta etapa: Construcción del Mapa Conceptual parte de la organización de las proposiciones en el orden que los niños y niñas elijan. Una vez construido el mapa se realiza la lectura completa del mismo en forma individual y grupal, se identifican y construyen las relaciones horizontales o proposiciones de segundo nivel.

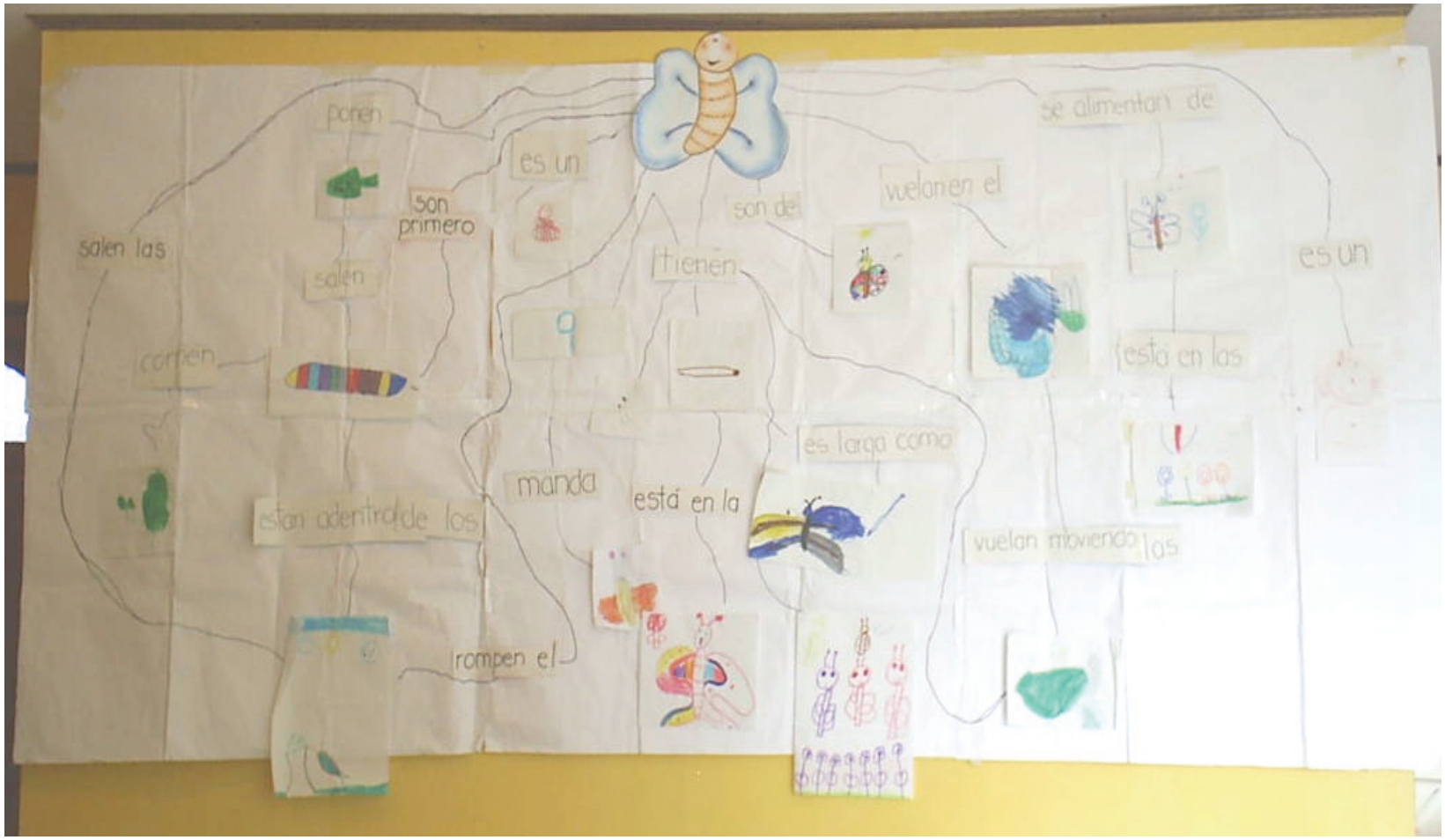
En forma conjunta al proceso de exploración, el equipo investigador se dio a la tarea de profundizar las bases conceptuales existentes sobre el desarrollo del pensamiento infantil y Mapas Conceptuales. El trabajo de campo se realizó a través de tres visitas semanales, con una duración de 30 minutos por sesión. La implementación de la propuesta requirió de 12 sesiones para el nivel de Transición y 15 sesiones para el nivel Interactivo II. Aunado al trabajo de campo se realizaron capacitaciones dirigidas a las docentes colaboradores sobre el uso de mapas conceptuales

La información obtenida durante la aplicación de la Propuesta Metodológica Inicial pasó por un proceso de análisis en ambas poblaciones de forma particular y comparativa.

Se presenta a continuación, fotografías correspondientes a los Mapas Conceptuales construidos por los niños y niñas participantes en la investigación.



Mapa Conceptual "El Conejo" elaborado por el grupo Interactivo II, Centro Educativo Domingo F. Sarmiento, Dulce Nombre, Cartago.



Mapa Conceptual "La Mariposa" elaborado por el grupo de Transición, Centro Educativo Fray José Antonio de Liendo y Goicoechea. Paraíso, Cartago.

5 Resultados del proceso de investigación:

Los siguientes resultados se abarcarán según las categorías de análisis contenidas en la investigación. Estas son:

5.1 Metodología aplicada en la implementación de la propuesta

La aplicación metodológica de la propuesta elaborada por el Equipo de investigación, tuvo moderados cambios lo que evidencia una estructura flexible, es decir, permite la adaptación pertinente, según las características y necesidades de la población en la que se implemente. Entre las modificaciones realizadas a la propuesta están: a) la realización opcional de las actividades introductorias, b) el orden no consecutivo de la ejecución de algunas etapas y pasos, c) la ejecución conjunta de algunos de los pasos de las etapas. Debe mencionarse además, que el número de sesiones requeridas para la construcción de los Mapas Conceptuales varió para cada población, sin embargo se destaca que el número de sesiones no es lo verdaderamente importante, sino la construcción de conocimientos, la disposición y entusiasmo de los niños y niñas desde el inicio hasta el final del proceso y todo cuanto se generó en el proceso en sí.

5.2 Proposiciones contenidas en los Mapas Conceptuales

Las proposiciones contenidas en los Mapas Conceptuales en ambas poblaciones, constituyeron la columna vertebral de los mismos. Éstas se caracterizaron por su estructura gramatical correcta.

La construcción de las proposiciones se originaron a partir de ideas espontáneas, generadas por conocimientos previos, experiencias directas e indirectas de los niños y niñas, partiendo de numerosas y diversas preguntas pedagógicas por parte del equipo investigador las cuales generaron amplia información sobre el tema seleccionado por ellos y ellas. Como bien lo menciona Ausubel (1918 citado en Enciclopedia de la Psicopedagogía), el docente debe partir de los conocimientos previos de los niños, de manera que las conexiones generan Aprendizaje Significativo. El análisis de los Mapas Conceptuales confirman la flexibilidad y socialización del pensamiento infantil, así como características de yuxtaposición y sincretismo, expuesta por Piaget (1967). Gran parte de las ideas aportadas constituían desde el principio proposiciones, otras necesitaron de los procedimientos establecidos en la propuesta para ser transformadas en proposiciones, lo cual abarcó el tiempo necesario para los niños y las niñas, sin ser esto una limitante para el proceso de investigación.

5.3 Representaciones gráficas realizadas por los niños y niñas participantes.

Los niños y las niñas de ambas poblaciones lograron representar gráficamente todos los conceptos contenidos en las proposiciones que ilustraron el Mapa Conceptual "El Conejo" y el Mapa Conceptual "La Mariposa". Según la teoría de Lowenfeld (1958) los dibujos elaborados por los niños y niñas reflejan características de la etapa pre-esquemática caracterizadas, por el mismo autor, por su forma definida, y conciente que superan la etapa del garabateo, al igual se presentan dibujos con características de la etapa esquemática que, según Lowenfeld (1972), éstos se caracterizan por contener línea base, línea del cielo, elementos ambientales inmersos en un contexto, desviaciones al exagerar elementos significativos dentro del dibujo. Cabe destacar que existieron casos en los cuales se evidenció un desarrollo gráfico superior con respecto a su edad.

5.4 Preguntas pedagógicas formuladas por el equipo investigador.

Las preguntas pedagógicas formuladas por el equipo de investigación poseían, según Huck (1976) una finalidad clara para facilitar y orientar el proceso de construcción del pensamiento de los niños y las niñas, así como continuidad, con el fin de profundizar sobre una respuesta o bien aclararla. Uno de los aspectos relevantes de la formulación de preguntas fue el hecho de que partieron del conocimiento previo de los niños y las niñas y no de un nivel de conocimiento determinado por el adulto, reafirmando la teoría del Aprendizaje Significativo de Ausubel (1918, citado en Enciclopedia de la Psicopedagogía) y la teoría de Piaget (1967) sobre construcción del conocimiento, todo dentro de un proceso de enriquecimiento por interacción colaborativa, como lo señala Vygotsky (1930, citado por Riviere 1994). Se recalca que no hubo formulación de preguntas por parte de los grupos participantes. Así mismo el tipo de pregunta no fue analizado por su frecuencia, sino por su función según las etapas

y los pasos que se ejecutaban en el momento, éstas abarcaron según la clasificación de Huck (1976) preguntas de memoria, comprensión, interpretación, aplicación y análisis.

Algunos ejemplos de las preguntas generadoras claves utilizados por el equipo investigador y que generaron amplia información son las siguientes: ¿Qué es un conejo?, ¿Qué tiene el conejo?, ¿Qué son las mariposas?, ¿De qué se alimentan las mariposas?, ¿Los insectos son animales?

6 Conclusiones

A continuación se presentan las conclusiones por categorías que emergieron del proceso y análisis de la presente investigación:

6.1 Pensamiento Infantil

- El proceso de construcción del pensamiento verbal y gráfico evidenció un gran valor emocional, afectivo, diversidad cognitiva, flexibilidad, socialización y descentralización del pensamiento a partir de constantes crisis cognitivas, cuestionamientos individuales y colectivos, propios del proceso, que ampliaron y transformaron progresivamente los conocimientos de los infantes, partiendo siempre de sus conocimientos previos.
- Las representaciones gráficas realizadas por ambas poblaciones se presentan características correspondientes a las etapas pre-esquemática y esquemática del desarrollo gráfico según Lowenfeld.
- La acción colaborativa, fortaleció la práctica de valores, dinamizando los procesos de creación del conocimiento, fomentando el aprendizaje por recepción significativa, además de un progresivo desarrollo de independencia que afirmó actitudes positivas, como son la toma de decisiones, la resolución de conflictos sociales e individuales.

6.2 *Propuesta Metodológica para la construcción de Mapas Conceptuales*

- El proceso de construcción de los Mapas Conceptuales logró evidenciar la construcción y organización del pensamiento infantil, partiendo de los conocimientos previos que poseían.
- La Propuesta Metodológica para la construcción de Mapas Conceptuales posee una estructura flexible que permite cambios de orden de ejecución de etapas y pasos según las características y ritmo de trabajo de la población infantil.

6.3 *Papel del y la docente*

- El papel mediador del equipo investigador fue un elemento fundamental que favoreció la exploración del pensamiento infantil a través del uso de preguntas pedagógicas en un tiempo flexible y adecuado al ritmo de construcción del pensamiento infantil lo cual guió la construcción de los Mapas Conceptuales.
- Una sólida formación teórico-conceptual sobre el desarrollo del pensamiento infantil, la pregunta pedagógica y las características maduracionales del estudiante, permite a los y las educadores desarrollar procesos metodológicos pertinentes al nivel de desarrollo y al contexto de los niños y las niñas.

6.4 Expectativas del Equipo investigador

- Las capacidades integrales, la construcción, la organización y la flexibilidad del pensamiento de los niños y niñas superaron las expectativas del equipo investigador acerca del pensamiento infantil.
- La investigación educativa es clave para responder a la demanda educativa y a los cambios evolutivos de las capacidades y necesidades de los niños y niñas desde la edad preescolar.

7 Bibliografía

Badilla, E., Chacón, S., Jinesta, M. (1987). Reestructuración Pedagógica sobre Aprendizaje. San José. Costa Rica: Universidad de Costa Rica, Facultad de Educación.

Cañas, A. J., Novak, J. D. & González, F. M. (Eds.) (2004). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, España: Universidad Pública de Navarra.

Chacón, S. (2006). Entrevista personal. Preguntas Pedagógicas. San José. Costa Rica. Universidad de Costa Rica.

Costa Rica, Ministerio de Educación Pública. (2000). Programa de Estudios del Ciclo Materno Infantil. San José.

Costa Rica, Ministerio de Educación Pública. (1996). Programa de Estudios del Ciclo de Transición. San José.

Figueiredo, M., Lopes, A., Firmino, R., de Sousa, S. (2004) Things We Know the Cow: Introduction to Concept Mapping in a Preschool Setting. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. 2). Pamplona, España: Universidad Pública de Navarra.

Furth, H. (1974). Las ideas de Piaget y su aplicación en el aula. Buenos Aires. Argentina: Kapeluz.

Ginsburg, H., Opper, S. Piaget y la Teoría del desarrollo intelectual. España Universidad de Cornell: Prentice Hall Internacional (s.a).

Huck Ch. (1976). Children's Literature in the Elementary School. United States: Third Edition Holt.

Lowenfeld, V. (1958). El niño y su arte. Buenos Aires. Argentina: Kapelusz S.A.

Lowenfeld, V. (1972). Desarrollo de la capacidad creadora. Buenos Aires. Argentina: Kapelusz S.A.

Novak, J & Gowin, B. (1988). Aprendiendo a aprender. Barcelona, España: Martínez Roca, S.A.

Paissan, M (2002-2004). Teoría del Aprendizaje Significativo por David Aussubel (1983) extraído el 18 de enero del 2006 de http://www.educainformatica.com.ar.

Piaget, J. (1967). El Juicio y el razonamiento en el niño. Estudio sobre la lógica del niño. (3º ed). Buenos Aires: Guadalupe.

Riviere, A. (1994). La Psicología de Vygotsky. Madrid. España: Visor Distribuciones.

Vygotsky. (2003). Vygotsky y la Pedagogía. Daniels Harry. España: Paidós.

Piaget, J. Una didáctica fundada en la psicología de Jean Piaget. Aebli, H. (s.a).

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LEARNING WHILE HAVING FUN
CONCEPTUALIZATION ITINERARIES IN KINDERGARTEN
CHILDREN EXPERIENCES WITH C-MAPS IN AN ITALIAN SCHOOL

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Abstract. The activities were organized by a group of teachers to promote the creation of scientific thinking and acquire progressive competence through observation, manipulation, discovery and reflection. Experiences stimulate and motivate children to learn, promoting curiosity towards reality. Curiosity is related with the pleasure of learning and discovering. It is a cognitive curiosity that is originated and nourished starting from the children's current knowledge.
Children are positively motivated to learn with a metacognitive approach, situating experiences in Vygotskij's proximal development area (known as potential development area), which is a emergent area of personality in strong expansion during childhood. The concept maps built by the children are situated in these learning contexts. They are a real metacognitive structure that stimulates reflection and organization of experiences, making meanings and knowledge emerge in a personal way.

1 Introduction

Concept maps have been used in Falconara Alta kindergarten with 4/5/6 year children for a few years in order to promote significant learning. Our school participates in the MIUR pilot project "The Words of Science", which is based on direct observation and manipulation of object and use of verbal, iconic, musical and kinesthetic languages to describe properties of objects and environment. All teachers in the school were involved in the project. This paper includes two c-maps that we received from Paola Conversano, a teacher at "Collodi" School in Fano. The project implemented in Italian schools is similar to the American project SCIS and aims at presenting sciences as an active process, centered on a limited number of unifying concepts conquered through direct experiences on objects, year after year. A qualifying aspect of the experience is the construction of concept maps using drawings made by children after manipulation and clinic conversation.

Clinic conversation can be defined as a means used by teachers to investigate children's spontaneous knowledge on a specific issue or concept. Knowledge background is the fundamental starting element for successive learning. The objective of Clinic Conversation is to understand the child's thought and concept formulation process (E. Damiano 1995 – "Didattica per Concetti" – Juvenilia Milano 1995).

Concept-based teaching places the child in the centre of the learning and knowledge building process. The innovative aspect of this method is that the teacher performs his/her teaching action starting from the concepts expressed by children both verbally and through actions on objects. Concept-based teaching recognizes the child's capacity to conceptualize.

The teacher's action and the school experience are a significant opportunity to help and orientate children towards the systematic discovery of the world, starting from the child's existing knowledge built on his/her personal experiences.The teacher does not interfere or superimpose with the children's knowledge. The teacher attempts to give children the necessary tools to de-construct their spontaneous opinions and progressively reconstruct more adequate concepts in order to efficaciously deepen their knowledge.

2 Learning laboratories

The teacher's task is to build itineraries to involve children in stimulating activities, direct their energies towards complete, exhaustive learning, while maintaining a high level of interest. The importance of games during the acquisition of knowledge, the repetition of activities in multiple creative contexts allow children to develop observation techniques and activate strategies that are finalized to predefined goals, not random.

Experiences concretize and promote objectives and activities in continuous open processes started by children to build ways of thinking and interpreting reality. The conquer of language lays in the centre of this arduous

transition from “doing” with things to mentally “doing”. Maturation occurs through an assimilation/accommodation process.

Another methodology used with children is Cooperative Learning for the development of social abilities and group learning. Children are divided in small groups and tell, describe, remember, share and collect perception and ideas in turn. Cooperative Learning is a teaching/learning method whose significant variable is student cooperation. (Insegnare e apprendere in gruppo di Mario Comoglio – Miguel Angel Cardoso Las Roma)

Maps have proved useful for all itineraries, since they stimulate and promote reflections in children, with regard to organization of experiences and make learning and knowledge emerge in a personal, creative way, while telling the concept map.

Comparison and sharing favored the development of verbal and iconic language, together with socialization. Novak (2001) states: “we found that concept maps are a useful system to help teachers organize knowledge for teaching and a good method for students to discover key concepts and principles contained in classes, readings and other teaching materials”.

2.1 Itineraries with construction of c-maps by kindergarten children

Title: The world of plants

(Many children consider plants to be simply trees)

Educational goal: make children understand that plants are very similar in many things, but different under many aspects.

Procedure description:

Conversation - Children sit in circle and establish shared rules of social behavior: taking turns, listening, establishing sitting modes, keeping the task, participating, asking for explanations, expressing non-verbal encouragements)

Step 1:

1 .Always start from the spontaneous knowledge children have on plants during conversation
2. Stimulation question asked by the teacher: can plants be found everywhere?
- Answers by children:
- There are trees in the garden
Teacher: Are there trees at the river mouth?
Children make hypotheses.
- No, because there are no trees
- There are no leaves
- There are only small plants
- There are no plants
- Flowers are flowers, they are not plants.
Task: to find main differences between tall plants, low plants, flowering and non-flowering plants during trips to school garden, river mouth and wood (Arboretum with a variety of plants).

Step 2.1: Exploration Game
Observation - Discovery

Trips to garden, river mouth, wood where children play the following game:
look for a tall plant. Once they find it, each child must touch and hug the plant.
Question: How did you find the plant?
Children's answers:
Alessia: I looked for the tree
Matteo: I chose the tallest tree
Vanessa: the tree is a tall plant

Jacopo: the tree is big and tall because of branches
Teachers took Jacopo to touch a shrub, which has branches just as a tree, to see that height is not determined by the presence of branches.
Linda: the plant is tall (she touched the tree), instead this plant is low (she touched the shrub).

The exploration game continues searching for low plants.



Figure 1. A.: i chose daisies, because they were low and close to the ground.

Both misknowledge and first correct concepts emerge during this interaction process, through conversation, with perception-evocation and reflection.

Starting from a perceptive base, through senses, children start to "remember" what they already know about this topic. Through evocation children slowly build meanings on what they have seen, heard, touched. These are fundamental itineraries for scientific concept building.



Figure 2. Group work: the task consists in looking for a plant, finding it and drawing it.

Step 2.2
Group work: the task consists in looking for a plant, finding it and drawing it.
Children perceive the learning goal as important and have the expectation to reach the goal with the help and assistance of their group mates.
Sentences: the teacher said to draw only tall plants.
- Did you see it? There are no leaves.
- I saw it. There are just a few leaves.

- I will put just a few leaves in the drawing.
- Ok
- It is still a tall plant.

Children build the first meanings through dialogue, observation and reflection, sharing and helping each other (Cooperative Learning).

Active and creative participation, careful observation of experiences stimulate curiosity and motivate children to ask questions and make first hypotheses: these are fundamental itineraries for the construction of a concept map for the experience and/or scientific concept.



Figure 3. Group map

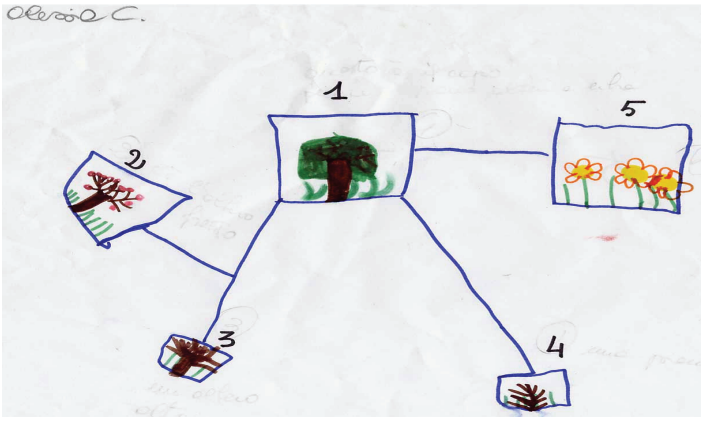
Step 2.3

Children are asked to draw an element from the experience and place drawings in the gym, starting from the important drawing (with all the plants they have discovered) and using different materials (sheets, color pencils, strings, tape).

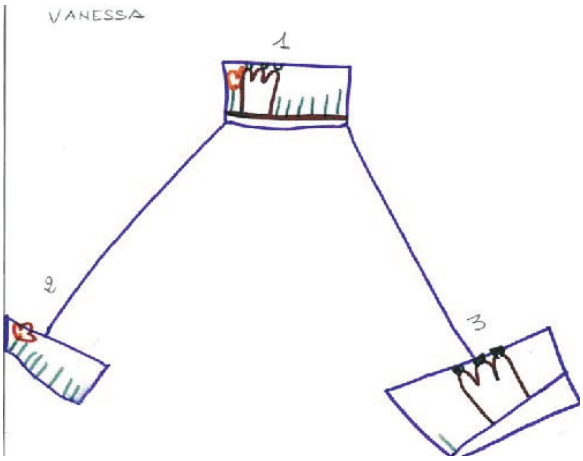
Brainstorming for map construction: children share perceptions and organizations of their experience (Cooperative Learning). Children establish the first relations between words and drawings through language and conversation, guided by the teacher.

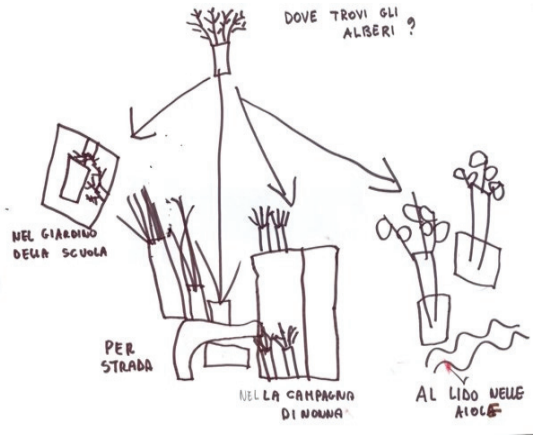
Task: to positively motivate children to learning, from a metacognitive viewpoint, offering experiences that stimulate curiosities through games (with different materials and different spaces).

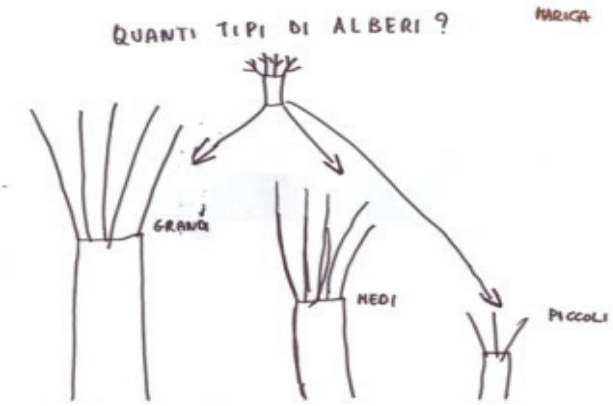
2.4 Each child tells the experience with map construction.



1) This is the most important because there are trees and grass
2) a flowering tree
3) a tall tree
4) a low plant
5) low daisies







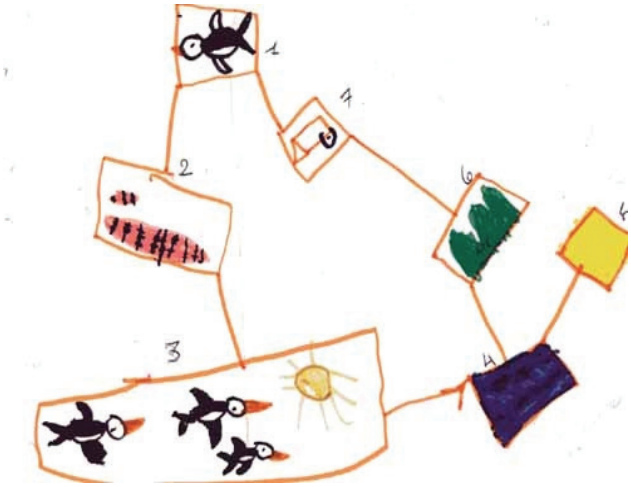
2.5 Swallows

A question is asked to find out what children know about the word "Migration"

Why do swallows migrate?

This question arouse the children's curiosity and interest immediately, resulting in more questions. At the end of the experiences the children:

Explain why swallows migrate with a concept map

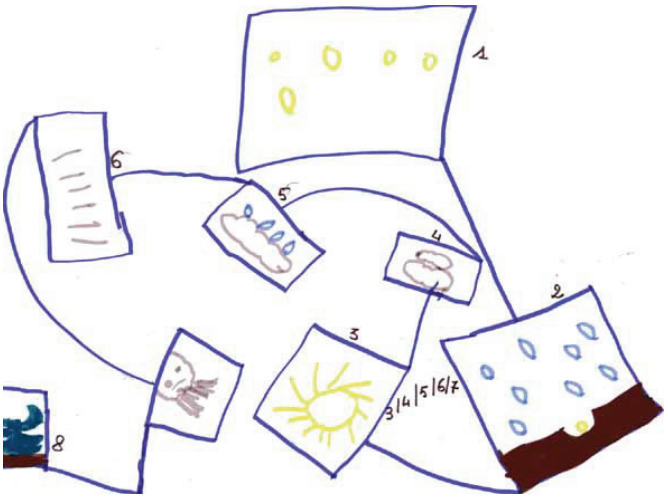


1) swallows leave;
2) swallows eat worms and cannot find food in winter in Italy;
3) swallows go to warm countries in groups, because baby swallows must stay in the group not to get lost;
4) swallows fly over the sea;
5) swallows pass the sea and reach the desert;
6) swallows go through hills and mountains;
7) finally swallows arrive in warm countries and build their nest until spring arrives in Italy.

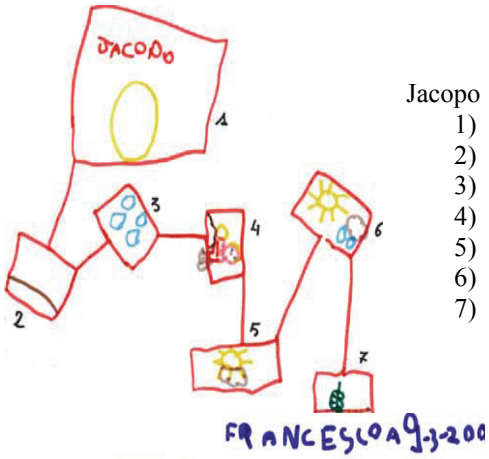
2.6 Sowing

Children sowed in October and plants are checked after a few months to see if they have grown.
Children tell their experience through successive drawings, where they show different spatial-environmental situations over time.

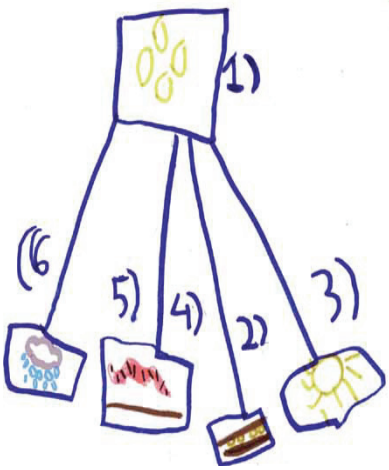
Telling the experience with a map



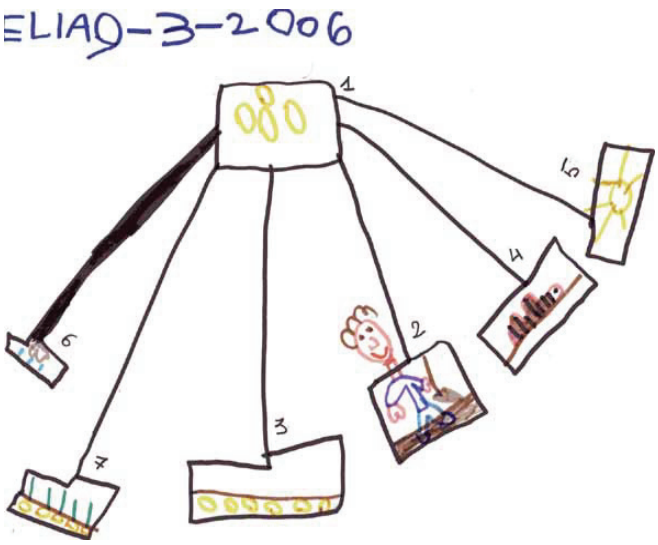
1) seeds
2) seeds were put on the ground
numbers 3-4-5-6-7 show the passing of time
8) seeds grew into a not very tall plant



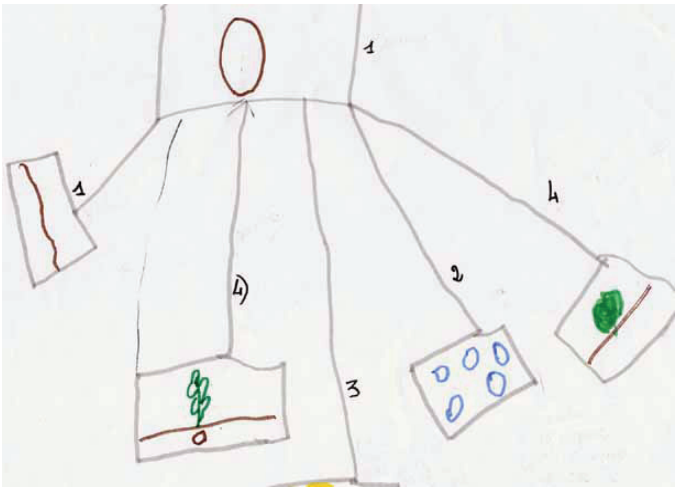
Jacopo
1) the seeds and the soil for the seeds
2) the rain makes the plant grow
3) it's me planting the seeds
4) sunshine makes the plant grow, not the cloud
5) rain and sunshine make the plant grow
6) the plant has grown
7) the plant grew because of all these things



Francesco: here I tell what seeds need to grow
1) seeds
2) seeds are in the ground
3) sunshine makes the plant grow
4) a worm
5) this is the work done by the worm
6) rain makes the seeds grow



Elia
1) seeds
2) it's me digging the soil
3) I put the seeds in the ground
4) we found a worm
5) the plants need sunshine
6) the plant grew a little
7) the plant



Davide: this map is about seeds
1) the seeds
2) I planted the seeds
3) We let the seeds grow
4) I moved this link here because I made a mistake
5) And then the seeds grew.

2.7

Each drawing made by the child included in the concept map is related with the child's thought. Situations propitious to evolution of one specific component are also propitious for the development of other components.

3 Conclusions

The teacher asks a question to the children: what does "building a map" mean for you? With this question we wanted to clearly identify the children's perception of c-map building. We were aware of the way we used to give guidelines, but we did not know how children would receive our guidelines in making c-maps, because approach to the method is always a subjective perception.

Answers given by children:
1) – Do you like building maps in a group? (teacher)
2) **P:** each of us made a drawing on the growth of seeds
3) **T:** we put the first important drawing on the table
4) **F:** from the main drawing we linked strings and attached them to other drawings with tape
5) **M:** first we thought about the seed experience, then we spoke about it.

Question made by teacher to stimulate children: Do you like building maps by yourself?

1) (As one): it's fun;
2) Jacopo: the map is not a drawing and it's nice because I can say everything I have in my mind and I can draw all the boxes I want;
3) Davide: I can make a lot of drawings and tell a lot of things;
4) Francesco: I am curious to see what is in each box;
5) P: we make maps to learn.

4 Summary

In conclusion, each child wants to express himself/herself uniquely in the c-map. Children are not inclined to share their ideas with other children or follow the group. They prefer to work alone, because the c-map is perceived as an individual sequence of situations, which express the peculiarity of the learning process. On the other hand, children like to discuss and talk about their experience, both during implementation and after conclusion.

Having the same structures, maps immediately permit visual reading. They provide a common starting point, from where similarities and differences can be immediately identified by children, stimulation meditation, language and socialization with other children. They are an easy, creative tool used by children to organize and represent their knowledge. In their own words, "they can tell what they have in their mind and open as many boxes as they want".

5 References

Damiano, E. "Didattica per Concetti. Juvenilia Milano, 1995.

Novak, J. D. L'apprendimento significativo. Le mappe concettuali per creare e usare la conoscenza, tr. it. Erickson, Trento 2001

Novak, J. D., & Gowin,. Imparando ad imparare tr. it.,Sei Torino, 1984.

Piaget J., Il linguaggio e il pensiero del fanciullo, tr. it. Giunti, Firenze 1968.

Piaget J., La costruzione del reale nel bambino, tr. it. La Nuova Italia, Firenze 1979.

Vytgoskyij L.S., Il processo cognitivo, tr. it. Boringhieri, Torino 1980.

Vytgoskyij L.S., Pensiero e linguaggio, tr. it., Laterza Bari 1992.

M.Comoglio-Miguel Angel Cardoso , Insegnare e apprendere in gruppo, Las-Roma

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LESSONS LEARNED FROM UNSTRUCTURED CONCEPT MAPPING TASKS

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Abstract: Two college of education faculty incorporated online concept mapping assessments in their fall 2005 distance education courses, varying in terms of content depth and participation. Students expressed great interest in mapping as an alternative form of assessment for distance courses, and performed adequately on assigned tasks. Attempts to involve students in collaborative pre-mapping and mapping were not entirely successful, as most students expressed more interest in developing individual maps, at least for purposes of assessment. For assessment purposes, recommendations include focusing student maps on concise content segments and using pre-selected terms to reduce the subjectivity of map scoring. For higher-order learning purposes, recommendations include gradually bridging to more open-ended maps, with increased content complexity scaffolded by mapping in small groups.

1 Introduction

Concept mapping serves multiple purposes in providing instructors with an assessment tool to determine what students know about a subject and how that knowledge is structured, and in providing students with an active learning tool to build and revise their own model of understanding. A concept mapping task begins with the instructor selecting a limited domain of knowledge to be mapped by the student (Novak & Gowin, 1984). This knowledge domain should be tied to course material such as required readings, a lab experiment, or an applied problem. The student lists key concepts in the domain and arranges them from inclusive to general and by type. The student completes a concept map by drawing lines between concepts to illustrate relationships and by writing proposition statements on these connecting lines to describe the nature of the relationship. For maps that depict multiple knowledge domains, students may also include cross-links to show how concepts that are not directly connected relate to one another on some higher level.

To use concept maps for assessment, at least three things must be accounted for: a task with directions for creating a map, some format for the student's response, and a scoring system (Ruiz-Primo & Shavelson, 1996). Tasks vary by constraints, with some providing pre-selected terms or propositions to students for mapping, and others asking students to generate their own list of terms or propositions. Response formats vary by mode, including paper and pencil, computer-generated, and interview whereby someone other than the student may generate a map to represent the student's oral responses. Response formats also vary by characteristics and difficulty, with some providing an easier fill-in-the-blank map structure for students on a partially-created map, others providing computer pull-down menus with relationship statements already defined, and some providing no map elements ahead of time.

A variety of methods are available for scoring concept maps. Scoring systems may include a comparison of the student-created map to an expert or criterion map, a computed score based on map elements, or both (Ruiz-Primo & Shavelson, 1996). One of the earliest and best-known scoring systems involves a holistic score computed from a sum of correct link-node relationships (1 point), cross-link relationships (2-10 points), structural hierarchies (5 points), and embedded examples (1 point) (Novak & Gowin, 1984). McClure, Sonak, and Suen (1999) outline at least two additional scoring systems: structural, or computing a score from higher-level structures, cross-links, and propositions; and relational, or computing a score from propositions alone.

The relational method is touted for its ease of use, mechanical simplicity, and increased reliability, allowing scores to be easily defended (McClure et al., 1999). Others suggest, however, there is too much data in concept maps to focus on relationship statements alone (Cañas et al., 2004). And the volume of data held in concept maps is increasing through new tools such as CmapTools (IHMC, 2006) and the Visual Understanding Environment (Tufts University, 2005). Students can now collaboratively edit concept maps online and attach a multitude of resources to developed concepts (e.g., URLs, images, notes, videos, digital library resources), enhancing the static *concept* map to a more descriptive *content* map with attached external resources.

Scoring maps on the basis of multiple characteristics takes time and increases cognitive load for the scorer, particularly for the new *content* map format with multiple external resource attachments. It is understandable why some would limit the scope of mapping assessments to select-and-fill-in terms on a pre-structured template, and to

no surprise such maps correlate closely with standard multiple choice tests (Schau, Mattern, Zeilik, Teague, & Weber, 2001). They should, since students are not creating their own structure, but repeating core knowledge as on a multiple choice test. A problem exists, however, in that restrictive fill-in-the-blank maps limit the knowledge students can represent (Ruiz-Primo & Shavelson, 1996). A great need still exists for authentic maps that require learners to integrate external resources.

Following constructivist pedagogy, mapping should involve merging one's existing knowledge about a subject with new, external information through recursive cycles of building and revising. In the information age, more than ever students need to make use of tools that allow them to integrate extensive online resources with their own personal knowledge maps, as they constantly update their understanding with new information to solve real problems. Those interested in mapping as a constructivist learning activity and not just a lower-order assessment, can't simply limit the student task to a few terms that fit neatly into a template. A compromise is needed, however, between overly-simplistic maps that are easy to score but tell us little about student knowledge structures, and more complex maps that are valuable learning tools but very difficult to score. Or, can we have our concept map cake (higher-order learning), and assess it too? The cases presented here describe lessons learned by two instructors as they sought to balance student learning through unstructured mapping tasks with the realities of scoring.

2 Procedures

During the fall semester 2005, two university faculty implemented online concept mapping in their graduate education classes. Both classes were taught at a distance using the university's WebCT Vista course management system. The difficulty in delivering and securing traditional tests at a distance is well known (Shyles, 2002). Online concept mapping provided the investigators with an alternative assessment to gauge their students' understanding of course topics. Two small classes participated in the study during fall 2005: Computer Applications and Curriculum Integration (ECI 511), and Classroom Assessment and Evaluation (EAC 595). Both classes were taught completely online with 10 and 13 students completing each course and all embedded mapping assignments respectively.

Course management systems rarely if ever include concept mapping capabilities, thus we selected a third-party tool to meet our needs--CmapTools (IHMC, 2006). The freeware CmapTools enabled our students to develop individual online concept maps and attach a multitude of resources to developed concepts (e.g., Web links, image files, word processed notes, video clips, etc.). Further, Cmap supported collaboration among students with co-edit features and built-in discussion boards and chats. The ability to attach notes to student maps was desirable for feedback and critiques. We utilized the public CmapServers provided through IHMC to establish student mapping spaces online. These electronic folders were password-protected with access granted only to the instructor and individual students.

In ECI 511, students completed three mapping tasks during the semester: a comprehensive map covering eight class sessions on different technology integration topics (e.g., hardware and software, standards, theoretical foundations); a more focused map covering two class sessions on uses of the internet in the classroom; and a final map covering one class session on factors influencing technology integration. Students were provided with no terms in advance; their maps were completely unstructured and built from self-selected terms. Students were required to integrate electronic copies of assigned readings in their maps to illustrate where they found depicted relationships. Students worked entirely alone on their first map. For their second and third maps, a discussion board was employed to assist students in collaborative pre-mapping by identifying relevant concepts from the readings as a group, before they created maps as individuals. Students were given the option of collaboratively developing their third map with another classmate.

In EAC 595, students completed two mapping tasks as individuals during the semester, covering concepts associated with assessment and evaluation. The first map was optional (non-graded), and completed at mid-semester covering nine weeks of course content. Students opting to turn-in a map at mid-semester received detailed individual feedback. These initial maps were then used as the basis for a second map submitted at the end of the semester covering all course work. An asynchronous communication tool was employed in this class as well, with students developing a list of terms throughout the semester on a group-edited wiki, then choosing their concept map terms from the wiki. Students were required to include at least 50 terms from the wiki on their second concept map. Additional terms not on the wiki could be included if students so wished.

3 Data Sources and Analysis

Through our case studies, we sought to answer the following questions regarding online concept mapping in distance teacher education courses:

1. How does the relative amount of content to map influence student mapping performance? We hypothesized that student map scores might be higher for short-term maps covering only 1-2 weeks of readings with less intrinsic cognitive load related to focused content sets, but that the level of detail included on longer-term, 8-week maps would be greater.
2. What are student preferences for participation in mapping activities, and is student mapping performance enhanced by a certain type of participation? We hypothesized student map scores might increase for mapping activities that included collaborative components--either group work to pre-select terms for mapping or actually co-editing a map with another student.
3. What are student preferences for assessment in online teacher education courses, and how is concept mapping received as an element of distance education assessment? We had no pre-conception for how students would react to concept mapping assessments in our distance classes.

We collected three student data sources to inform the questions: post-survey responses, a log of student questions posed regarding assigned mapping tasks, and the concept maps themselves. Student survey responses were summarized using descriptive statistics, and open-ended comments received by the 23 students were limited and concise enough to summarize thematically.

We initially pre-selected the relational method for our class maps to assign points for correctly identified propositions from course readings. Great variation was apparent across student maps in terms of propositions and other details, however. Since a student with 36 correct propositions and weak overall details (e.g., attached notes and resources), should not necessarily receive a better score than a student with 20 correct propositions and considerable map detail, the relational method was replaced. Variance in scoring widely divergent map elements on open-ended map assignments is known to be an issue, as it was for our classes (Shaka & Bitner, 1996). And as noted earlier, rather than limiting this divergence and student conceptualizations, we were interested in fostering and scoring it.

The relational method was replaced in ECI 511 with a holistic method, looking for evidence that students correctly identified key concepts from the readings, appropriate proposition statements, and attached at least some of the core readings or personal notes to appropriate concepts. Students received written feedback detailing any point deductions for leaving core concepts off their maps, for failing to detail concept relationships through proposition statements, or for failing to attach relevant resources. In EAC 595, the relational method was similarly replaced with a holistic rubric that included as criteria the quantity of words included (50 required from the class wiki), the inclusion of main course themes, and the accuracy of propositions. Admittedly subjective, both instructors found a holistic appraisal to be the single scoring method applicable to their students' open-ended or unstructured maps.

4 Findings

4.1 How does the relative amount of content to map influence student mapping performance?

The mean student grades on three mapping tasks in ECI 511 were: 16.6 out of 20 points (83%) (map 1 covering 8 weeks), 47.2 out of 50 points (94.4%) (map 2 covering 2 weeks), and 48.8 out of 50 points (97.6%) (map 3 covering 1 week). Student scores were the lowest for their first map, and near mastery for their other maps. In EAC 595, students only received a grade for their end-of-semester map (a possible 30 out of 1000 semester points). Using the rubric, the mean grade was 27.7 out of 30 points or 92.3%, which excludes zero grades given to two students who did not turn in the assignment. Three students did not turn in their optional concept map at mid-semester, and their grades were on the lower end of the scale (26.33 or 87.78%).

For ECI 511, the mean number of concepts identified on each of three student maps was computed, as well as the mean number of resources attached and proposition statements written, to provide a general picture of the detail students put into their maps. It was expected that students might identify more concepts, attach more resources, and develop more proposition/relationship statements, for their first map covering eight weeks of content than for subsequent maps covering smaller content segments. T-tests revealed no significant differences, however, in the

mean number of concepts identified, resources attached, or proposition statements written, between the divergent map 1 and the more focused maps 2 and 3. Mean values and standard deviations are provided in Table 1.

	# of concepts identified		*# of resources attached*		*# of proposition statements*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Map 1 (covering 8 weeks)	38.5	19.6	21.4	15.3	28.8	21.0
Map 2 (covering 2 weeks)	34.7	21.8	20.5	11.6	28.4	13.4
Map 3 (covering 1 week)	37.3	23.4	16.6	11.3	34.1	18.8

Table 1: Level of detail provided in ECI 511 concept maps covering different time periods.

On a Likert scale of 5 (strongly agree) to 1 (strongly disagree), students were asked to rate their agreement with the post-survey statements shown in Table 2. The percentage of students who agreed or strongly agreed is reported for each class, as well as the combined percentage across classes. Students in both classes generally agreed or were neutral that mapping 1-2 weeks of content, 1-9 weeks of content, and the whole semester week-by-week, could be useful mapping strategies. Students in ECI 511 who had experienced both short-term and long-term maps indicated a strong preference for mapping more focused content segments of 1-2 weeks. Students in both classes rejected mapping content from an entire semester at the end of the semester, suggesting that strategy would be less useful.

		ECI 511 n=10	EAC 595 n=13	Both n=23
% of students who agree or strongly agree with different applications of concept mapping:	Doing the first draft of the Cmap at mid-semester helped me with the final product.	not asked	4.5	n/a
	Do you agree/disagree that developing a Cmap that covers only 1-2 weeks' content could be useful?	100%	53.8%	73.9%
	Do you agree/disagree that developing a general Cmap that covers several weeks' content (e.g. weeks 1-9) could be useful?	40%	61.5%	52.2%
	Do you agree/disagree that building the Cmap week by week over the semester could be useful?	57.1%*	61.5%	60%*
	Do you agree/disagree that developing a Cmap for the whole semester, but only at the end of semester, could be useful?	0%*	15.4%	10%*

**for these questions, n=7 and 20 respectively*

Table 2: Percentage of students who agree or strongly agree with different applications of concept mapping.

4.2 What are student preferences for participation in mapping activities, and is student mapping performance enhanced by a certain type of participation?

As shown in Table 3, survey data illustrates that students generally agreed or were neutral regarding two suggested participation strategies: developing Cmaps by themselves versus co-developing Cmaps with another student. A strong preference for one mode over the other was not illustrated by the data, however students in ECI 511 were given the option of co-developing their final Cmap with another student and only two students chose to work collaboratively. In EAC 595, students were not given the option of working collaboratively on concept maps because of problems experienced earlier in the semester on group assignments. Students complained about different work schedules and the times they were available to work on projects. Most preferred to work as individuals.

		ECI 511 n=10	EAC 595 n=13	Both n=23
% of students who agree or strongly agree with different participation modes:	Do you agree/disagree that developing a Cmap by yourself could be useful?	100%	53.8%	73.9%
	Do you agree/disagree that co-developing a Cmap with another classmate could be useful?	40%	61.5%	52.2%

Table 3: Percentage of students who agree or strongly agree with the usefulness of different participation modes for concept mapping.

One participation strategy employed by both instructors was to provide students with collaboration tools (i.e., wikis or discussion boards) to discuss major course concepts, prior to their individual mapping. This strategy was assumed to help students extract and come to consensus on major and minor course concepts to be mapped, given the open-

ended nature of the task. Student actions did not illustrate useful collaborations, however. In ECI 511, students were given an optional (non-graded) discussion board to discuss major concepts that should be included in their second map, but only one-third of students took part in the discussion. Nearly every student participated in a separate graded discussion board to discuss concepts that should be included in their third map, but only one original post was recorded per student, and only three students posted replies to other students. To no surprise, the maps created by students following these limited discussions were not significantly better than the first map created by students without any direct discussion.

4.3 What are student preferences for assessment in online teacher education courses, and how is concept mapping received as an element of distance education assessment?

When asked to choose between a traditional exam and a Cmap assessment on their post-survey, a majority of students in both classes chose Cmap as shown in Table 4. When given more choices between a traditional exam, Cmap, applied projects, or a combination, a majority of students in both classes still chose Cmap, although applied projects and a combination of assessment methods were preferred by roughly a quarter of students in both classes.

		ECI 511 n=10	EAC 595 n=13	Both n=23
If you could choose between a Cmap assessment or a regular exam, which would you select?	Cmap	90%	69.2%	78.3%
	Regular Exam	10%	30.8%	21.7%
If you could choose between Cmaps, regular exams, or applied projects, which form of assessment would you select?	Cmap	40%	38.5%	39.1%
	Regular Exam	0%	15.4%	8.7%
	Applied Projects	30%	23.1%	26.1%
	Combination of Each	30%	23.1%	26.1%

Table 4: Percentage of students preferring different methods of assessment in distance teacher education courses.

As further evidence of student satisfaction with Cmap assessments, students in ECI 511 were queried on their post-survey as to the one thing they enjoyed most about the course. Five of ten students provided unsolicited comments suggesting Cmap activities were their favorite course element. When queried as to the one thing they enjoyed least about the course, no students disparaged Cmap. Similarly, three students in EAC 595 sent unsolicited email comments to the instructor about the value of Cmap to pull together various course concepts, even though one also noted that it was the hardest thing he had to do all semester.

As shown in Table 5, students in both classes generally agreed or strongly agreed that Cmap helped them to make connections within course sub-topics and between major course topics. Further, students were asked on their post-survey to describe what was most beneficial about Cmap activities. Nearly every student provided written comments that could be sorted in one of two categories--Cmap helped them synthesize and put together course material (e.g., "helped me to focus course concepts into a single picture," "putting what I had learned into an organized format"), or Cmap helped them make connections between course materials (e.g., "having to think about the terms and make connections," "forcing you to relate the topics"). Two students suggested the activities helped them to "remember" or "retain" course information better.

		ECI 511 n=10	EAC 595 n=13	Both n=23
% of students who agree or strongly agree on different values of concept mapping:	The Cmap activity helped me to make connections within a sub-topic of the course (e.g. classroom assessment techniques).	100%*	76.9%	85%*
	The Cmap activity helped me to make connections between major topics of the course (e.g. assessment and evaluation).	100%*	84.6%	90%*
	The Cmap activity was worth enough points in the course.	100%*	53.8%	70%*
	Please rate whether you agree/disagree the following course assignments were useful: Cmap assignments.	90%	not asked	n/a

**for these questions, n=7 and 20 respectively*

Table 5: Percentage of students who agree or strongly agree with different values of concept mapping activities.

Students were also asked on their post-survey to describe what was least beneficial about Cmap activities. About one quarter of students surveyed describe technical difficulties learning to use the software (e.g., "...it was difficult to figure out how to use the Cmap software"). At least three students expressed concern over the amount of time it took to create their concept maps, suggesting the hours involved were not worth the number of points awarded for the task (e.g., "...very costly timewise for only 30 points"). Only one student mentioned concern over mapping large chunks of content (i.e., "...having to do it on a huge amount of information").

5 Discussion

5.1 How does the relative amount of content to map influence student mapping performance?

Students in ECI 511 passed all three of their mapping assessments, with the lowest scores recorded for their first map. Further, the number of concepts identified, resources attached, and proposition statements written, remained similar between map one that involved considerably more content and maps two and three that involved less overall. The lower overall score and surprisingly similar level of map detail for map one may have reflected a combination of both intrinsic and extrinsic cognitive load factors. In terms of intrinsic cognitive load related to the content itself, for map one students were new to the course content and also mapping the most content of any of their assigned maps (eight weeks). In terms of extrinsic cognitive load or those variables outside of the content, for map one, students were simultaneously learning the process of concept mapping and the new Cmap tool. In fact, 12 out of 15 students originally enrolled in ECI 511 reported they had never created a concept map on a course pre-survey, thus these students were indeed novices who may have benefited from practice mapping before more demanding tasks were assigned. Managing a new strategy and tool as well as a large amount of content simultaneously may have impeded the students' ability to extract and structure all relevant concepts.

In retrospect, students should not have been assigned their most complex map first, but rather more conceptually manageable maps covering only 1-2 weeks of content. Students unfamiliar with the concept mapping strategy or a new mapping tool are likely to have a high external cognitive load, which should be offset by more manageable content chunks with lower overall intrinsic cognitive load. Conversely, students who have some familiarity with the mapping strategy and mapping tools are likely to have lower extrinsic cognitive load and should be ready to handle more intrinsic cognitive load associated with more difficult or more detailed content. Instructors should bridge to more cognitively challenging content chunks after students have mastered mapping basics.

In EAC 595, students who only submitted one final concept map had lower scores than those who had turned in optional maps at midterm and received instructor feedback. Iterative maps are one strategy that may be employed for managing large content chunks, as was the case in EAC 595. A map covering major topics from eight weeks of course content at midterm is no small map, thus the iterative nature of creating, receiving feedback, and revising a map in cycles, appears to have some benefit for at least some students. If instructors plan to use iterative maps that are revisited and revised over time, they may want to allocate at least some grade for preliminary maps to encourage all students to submit them. As with ECI 511, early and smaller concept mapping assignments may also help those students who are new to concept mapping or even resistant to the idea.

5.2 What are student preferences for participation in mapping activities, and is student mapping performance enhanced by a certain type of participation?

When concept maps are used as a learning tool in addition to an assessment tool, one must consider the potential benefits of grouping students together for work on a common map. As with the problem-based learning model, students may be able to manage more intrinsic cognitive load tied to ill-defined problems, if they divide their significant research requirements and collaboratively work to define and understand a complex issue. Benefits may ensue as collaborating students discuss and negotiate proper connections between concepts, and collaborating may serve a second purpose in helping students adjust to a new tool and support one another technically on their initial maps, managing extrinsic cognitive load as well.

Student actions in our classes, however, would indicate a preference for individual mapping over group mapping (i.e., choosing to work alone when given the chance to work collaboratively, limited collaboration with others on pre-mapping discussion boards and wikis). This preference may be related to our use of concept maps

primarily as an assessment tool. If learners perceived the task as one of individual assessment, which it was, they may have been less willing to contribute to group-edited discussion boards and wikis during pre-mapping, for fear of "giving away" all of their answers to other competing students. This preference may also be related to our distance learners who predominantly work full-time while taking our courses, and who might perceive scheduling a common time for synchronous group mapping to be a challenge in their busy daily schedule.

Fortunately, both issues are easily managed. Regarding the perception of competition from classmates on assessment tasks, convert the task into an authentic group project for a group grade. For pre-mapping activities, an improved structure would involve grouping 2-4 students into a team that would identify major concepts from readings to include in a group-edited map. Whole group identification of terms followed by individual mapping may be less effective than small group identification of terms followed by that same small group using their own terms on their own map. Regarding distance learners with different time schedules, it is possible for students to build maps asynchronously with Cmap, using built-in discussion boards to support group talk about map content.

5.3 What are student preferences for assessment in online teacher education courses, and how is concept mapping received as an element of distance education assessment?

Concept mapping assessments were well received by a majority of students in both classes, with survey data illustrating a strong student preference for mapping assessments over regular exams. Even when asked to select their preferred method of assessment between maps, exams, and projects, a majority of students chose maps, with about a quarter interested in projects or a combination of methods. In addition, students generally agreed or strongly agreed that Cmap activities helped them make connections between major topics and sub-topics of the courses. Further, most students provided written comments on their post-survey that would suggest the activities helped them to either piece together and organize course information or to understand how course materials were connected or related.

6 Future Directions

A number of task structures are possible in concept mapping. The simplest tasks involve students filling-in concepts on map templates, essentially classifying provided terms amongst others like it on the template (i.e., place these three provided concepts in the proper blanks on the template that already has 15 terms in it). A slight variation with more challenge involves filling-in the propositions on a template, which may or may not be provided to the learner. As noted, finding relationships between concepts is one of the more important aspects of connected understanding (Novak & Gowin, 1984; Schau et al., 2001). More challenging still are pre-selected term maps that require the learner to generate the basic structure, classify the terms, and find the relationships. These vary in difficulty by providing all the terms around some topic or seeding a partial set of terms around some topic that the learner must supplement with additional terms from their own memory. Finally, the most challenging maps of all involve open-ended mapping with little to no guidance provided other than a major topic. These maps require the learner to qualify or extract the most important concept units, generate a structure, classify the terms, and find relationships. The potential for learning is high, but so is intrinsic cognitive load, and this load only increases for online *content* maps that allow a student to justify or prove their map with evidence from external resources.

As shown in Figure 1, a tradeoff exists between structured and unstructured mapping tasks. For fill-in maps, students basically classify information--one thinking skill (Presseisen, 2001). For open-ended maps, students qualify terms, classify terms, generate a structure, find relationships, and perhaps, justify their map with evidence from external sources and draw conclusions on the basis of the map--multiple thinking skills. In our graduate classes, we are interested in fostering multiple skills and tasked individual students with developing complex, open-ended, content maps. Our graduate students were successful and capable of managing this task, and for the most part enjoyed the task, despite some evidence of both intrinsic cognitive load related to longer-term maps and extrinsic cognitive load related to their lack of familiarity with concept mapping and the Cmap tool. The tradeoff was our student maps were very difficult to assess with great variability among them. The relational scoring method was replaced in lieu of a holistic assessment that was admittedly subjective at best.

To maximize student learning while managing our own assessment challenges, in our future classes we plan to employ both pre-selected term mapping for assessments and open-ended mapping for learning activities. Pre-selected term mapping still allows students to practice several important thinking skills in classifying terms, finding

relationships, and generating an original map structure. At the same time, it restricts the students to work with the same concept set, so our assessment can remain much more focused on how these twenty or so terms are related by the students. Since propositions are a critical map element to assess, pre-selected term mapping will allow us to analyze relationship statements branching off of the same defined terms more objectively.

One concern with pre-selected term mapping is its ability to stifle student thinking about larger content sets. Student survey comments clearly illustrated the value they placed on "connecting" course concepts, thus we will also include some unguided or open-ended maps in our classes that allow students more freedom to interrelate divergent content domains, but only after students gain some familiarity with the mapping process and tools. Open-ended maps are difficult to use for assessment purposes, but they represent a useful educational strategy to help students reflect on several weeks' content, perhaps in preparation for an exam. Creating open-ended maps remains a challenge for students, thus we recommend leveraging the collaborative capabilities of Cmap, with small groups of students supporting one another as they work to relate extended course materials.

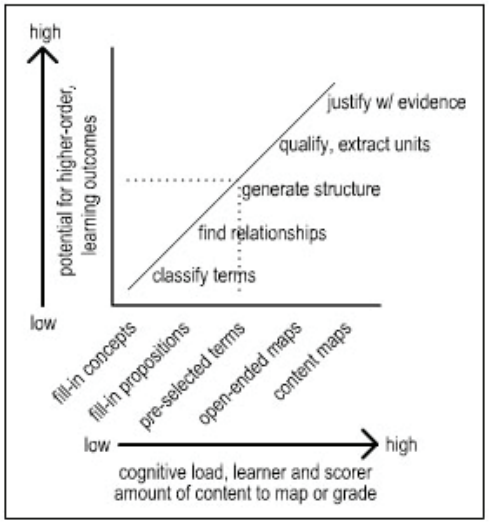


Figure 1: Tradeoffs between structured and unstructured mapping tasks.

7 References

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

IHMC. (2006). CmapTools: Knowledge modeling kit [Computer software and manual]. Retrieved February 14, 2006, from http://cmap.ihmc.us/

McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. *Journal of Research in Science Teaching*, 36(4), 475-492.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.

Presseisen, B. Z. (2001). Thinking skills: Meanings and models revisited. In A.L. Costa (Ed.), *Developing Minds: A Resource Book for Teaching Thinking* (3rd ed., pp. 47-53). Alexandria, VA: ASCD

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33*(6), 569-600.

Schau, C., Mattern, N., Zeilik, M., Teague, K. W., & Weber, R. J. (2001). Select-and-fill-in concept map scores as a measure of students' connected understanding of science. *Educational and Psychological Measurement, 61*(1), 136-158.

Shaka, F. L., & Bitner, B. L. (1996). Construction and validation of a rubric for scoring concept maps. In P. A. Rubba, P. F. Keig, & J. A. Rye (Eds.), *Proceedings of the 1996 Annual International Conference of the Association for the Education of Teachers in Science.*

Shyles, L. (2002, November). *Authenticating, identifying, and monitoring learners in the virtual classroom: Academic integrity in distance learning*. Paper presented at the meeting of the National Communication Association, New Orleans, LA.

Tufts University Academic Technology. (2005). *Visual understanding environment*. Retrieved October 15, 2005, from http://vue.tccs.tufts.edu/

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LOGICAL SYSTEMS AND NATURAL LOGIC: CONCEPT MAPPING TO FOLLOW UP THE CONCEPTUALIZATION PROCESSES

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Abstract. The concept maps built and shared in the internet through the CmapTools resources were used in this study to follow and to analyze the processes of concept construction in the school learning situations. The samples, from a Brazilian public school, built maps in the context of learning projects developed in a digital environment. Jean Piaget's Genetic Psychology and Epistemology, which supports the project method in use in the net environment, was chosen as a methodological-theoretical alternative to Joseph Novak's proposal that uses David Ausubel's Meaningful Learning. Moreover, we made use of Jean-Blaise Grize's Natural Logic to build the data analyses in natural language, comparing them with the evolution and modifications of the linking phrases in the concept maps.

1 Introduction

In the literature as well as and in meetings related to the new technologies and education, like the International Conference on Concept Mapping and the Brazilian Symposium on Informatics in Education, the growth of scientific production and the educators' interest on the use of concept maps became evident, especially for learning improvement and managing and organizing knowledge.

Through this resource we, researchers and teachers, are not looking for the punctual evaluation of the individuals' performances, but to the possibility of analyzing the development of their cognitive mechanisms throughout the evolution of the mapping sequence, created in their learning process. In general, the analysis criteria presented are quantitative (number of relevant concepts, counting of the correct propositions, etc.), or produce comparisons of the students' concept maps with the specialists´ (or teacher´s) maps to suggest the substitution of the propositions which are considered incorrect (Ahlberg et al. 2004; Conlon, 2004; Cunha et al. 2004; Rocha & Favero, 2004a and 2004b).

The foundations of the Genetic Psychology, in the body of Jean Piaget's Epistemology, explain the process of concept construction as a gradual and interactive dialogue between the individual´s logic systems and systems of meaning. The existing methods used for the evaluation of concept maps seem to be unable to encompass this kind of thinking about cognitive processes. In this article, we will briefly discuss an adaptation of Piaget´s take on learning to the concept maps, and propose a analysis model of conceptualization based on this perspective.

2 Concept Maps and Piaget´s Theory

Novak (1998) defines a concept map as a tool to organize and to represent knowledge. The concept map, supported by David Ausubel's (2000) meaningful learning theory is a graphic representation in two dimensions of a set of concepts built in a way that the relationship among them are evident. Two or more concepts, connected by linking phrases, create a semantic unit called proposition. The propositions are a particular form of concept maps in comparison to other types of communication. This is, precisely, the characteristic that favors our study, which strives for a new interpretation of this type of representation. We are not, however, proposing a substitution for Novak's contribution. Our goal is to add a more specific knowledge, which helps to analyze and to understand the cognitive mechanisms under a more systemic focus.

An evident fact is that the relationships in a concept map are established in language, that is, the words chosen by the author of the map represent the concepts and the respective linking phrases. It is interesting, however, to note that Piaget showed that the construction of meanings occurs even before the language acquisition (Piaget & Inhelder, 1976). Besides, the construction of a logic which organizes the subject's systems of meaning happens simultaneously at the beginning of his interactions with the knowledge objects (Piaget, 1996). At the beginning, this logic organizes the objects directly in the action (in this case, in the physical world, that is, to push, to grab, to put in

the mouth etc.). When these actions are performed through representations (semiotic function), and it becomes possible to use language, these systems of meaning can be evoked in the subject's discourse.

Ausubel (2000) defines concept as a perceived regularity in events or objects in a way that they and the propositions are the construction blocks of knowledge in any domain. This perspective implies in believing that the perceptive mechanisms are the means by which the concepts are acquired by the subject. For Piaget, however, the concepts are built from successive levels of awareness states which allow the subject to "internalize" actions and produce transformations (from a simple reconstitution of facts to reversible transformations, that is, operations) in the objects in thoughts (Piaget & Inhelder, 1976).This way, when establishing judgments, the individual *acts* over the concepts establishing relationships among them, or applying them on determined objects (Piaget, 1976). Regarding the language, a predication is required when establishing a judgement. Consequently, the establishment of relationships between concepts cannot be without verbs. With this perspective in mind, we state that, in addition to Novak's definitions, the presence of verbs in the linking phrases is an essential condition for a concept map.

For Piaget, each new concept is built by assimilation stages and consequent successive accommodations of new meanings. Each stage combines the previous ones, maintaining elements and relationships non-conflicting with the real state of the system (in the case of successful adaptations) and modifying (and not simply reorganizing or substituting) those elements and relationships that, due to a necessity of the action (of its means and objectives) or the transformations and operations in thought, became disturbances. About this, Piaget states that "a conceptual system, indeed, is such a system that its elements inevitably lean on each other, being at the same type open to all exchanges with the exterior. We can suppose the construction of an only concept A, as a classification starting point, etc. If it is really a concept, then it is already opposed to a non-A concept, which establishes a total and circular system since the first moment. In the case of a multi-conceptual system, it is impossible to characterize any concept without using others, in a process which is also necessarily circular" (Piaget, 1976).

A conceptual system characterized in this way is comparable to a structure, a theoretical construct extremely important for Piaget. According to him, the structure is the condition for possible knowledge. Shortly, we can say that a structure (particularly the cognitive structure): (a) contains elements and relationships which connect them without, however, being able to define such elements independently of the relationships; (b) can be considered independently of the elements which are part of it, that is, when abstracting the elements, it is possible to consider a relationship system or a structure "form"; (c) evolves from more elementary types up to the high order ones as the elementary structure becomes elements of higher order structures; (d) can be compared to another structure if it is possible to define an isomorphism which places each one of its elements in biunivocal correspondence and, respectively, each relationship which gathers them, in a way that the meaning of such relationships is preserved; and (e) contains sectors or parts called substructures which, depending on the relationship system that are part of them, may or may not present an isomorphism in relation to the structure as a whole (fractal) (Piaget, 1996).

3 Piaget´s logic

According to Piaget (1976), knowledge evolves to structure itself in systems of propositions, interdependent and dynamic. In higher levels, thinking would happen, therefore, through logic operations in the systems. The central idea is that the formalization (of relationship systems) is not stale, but a process, and it supports itself in dynamic structures. To state something is to operate with systems of meanings, and not only to draw from previously acquired (and complete) knowledge. Therefore, in a piagetian perspective, an important aspect in the analysis of cognitive processes is to observe these kinds of actions, or judgements, established by the individuals in their discourses. One of the "tools" for such thing is propositional analysis.

A proposition is a statement susceptible to qualification. That is, a proposition must have a meaning, so that it can be evaluated as true or false. This is important because, as expressed before, this type of representation allows for the observer to have a clearer evidence of the relationships established between concepts. Besides, the relationships established between different propositions (interpropositional operations) can also be analyzed, as well as operations inside a proposition itself (intrapropositional operations). A proposition is one of the ways in which the individual can structure his thoughts, and redefine them. Thus, propositional analysis is an important way of observing the conceptual relationships and their implications in one´s discourse.

For Piaget (Piaget & Garcia, 1989), there are implications between meanings from the more elemental levels of thought. In the case of the construction of concept maps, when we choose a relationship between two concepts (expressed by a linking phrase) we are performing a *meaning implication*. This piagetian construct, in short, is a way to look at the relationship between meanings established by the individual, and to analyze them in levels. These levels are the results of the development of structures which allow the subject, from a long process of construction of logic relationships (due to the situations faced by him), to expand his comprehension about the knowledge objects. This way, Piaget states that there is a Logic of Meanings which precedes the Formal Logic and that from the child's action up to his operations in thought there is a correspondence between the formal operations and the meaning implications. What happens is that the formal operations are sufficiently differentiated to allow its combination in a set system. In the case of the meaning implications, it is possible to observe the same formal operations performed in very particular contexts without, however, being necessarily general or applicable in other contexts.

In the following paragraphs, we will present an adaptation (Dutra, Fagundes & Cañas, 2004) of the meaning implication theory aimed at analyzing the concept maps, with special emphasis on the linking phrases. These criteria adapted from Piaget's theory allow not only for a more global analysis of the maps (or the subsystems emphasized in them) but also an analysis of the types of logic operations of thought involved in the isolated propositions or in their combinations.

A **local implication** can be defined as the result of a direct observation, that is, what can be registered of the object through observation of its context and its attributes. In a way, a local implication can characterize an object without, however, updating the knowledge about it. In a concept map, the local implications generally appear in the propositions with linking sentences which use verbs like "is", "has" etc.

A **systemic implication** inserts the implications in a system of relationships in which some generalizations and properties not directly observable start to appear. In this sense, the differentiations are not only perceived from qualities of the object, but inferred from it or from the action over it. In the maps we can perceive relationship systems (generally hierarchic) where there are implications between the concepts that, while not giving explanations or justifications, take into account some causes and consequences. Relationships between events and objects are established, but questions like "how?" and "why?" remain unanswered.

A **structural implication** broadens the previous ones because, here, the reasons and the "whys" show up. Piaget mentions that his level of implication is the comprehension of reasons and the discovery of the necessary relationships (Piaget & Garcia, 1989). Thus, more than knowing causes and consequences, the structural implications establish that conditions (in the logic sense) are essential for certain statements, in contrast to merely sufficient ones. In the case of the concept maps, we would have to combine a set of propositions so that we can have structural implications.

4 Natural Logic

Collaborating with Piaget for many years, Jean-Blaise Grize proposed to provide a model of discursive scheme analysis, that is, a content logic. In this sense, the Natural Logic consists of a model which deals with the common thought (non scientific) and, in this way, allows an exploration of the aspects related to the aspects of discourse which are not, in a way, objects of Piaget's model. The advantage of using such tool is to have a theoretical approach which deals with the cognition from corpus formed directly in the written or spoken language. For Grize (1996), the natural logic can only emphasize the aspects of the objects and the predicates that appear in the discourses. Based on this, he built a model which allows us to observe the building and determination of objects, and the operations used by the individual in order to achieve this. As the natural logic is an important part of our analysis model, we will describe some of these discursive operations.

When we speak of a class-object (a theoretical construct that could be loosely compared to a concept), the elements which are part of them are like ingredients and belong to what is called *bundle of the class-object*. Such elements can be introduced one after the other in the class-object through a family of operations (**operations over the bundles**) where four types are distinguished: to introduce a part of the object; to mark an internal process to the

object; to mark the object state, one of its ways of appearing or one of its qualities; and finally, to mark a dimension, a plurality, an extension.

The **retake operations** designate an operation family which is used to call the same object in another way. That is: introducing a term of close type (table ->furniture); presenting the object in another angle (metonymy) (bridge -> Golden Gate); establishing a judgement of value (father -> my hero); or emptying an object of its content (my computer -> this guy).

As for the **localization operation,** when it is applied to the judgement contents, it implies in localization in space, in time or even relative to other elements. For example, a statement like The Republic President is elected for seven years, cannot be taken as true or false unless in a certain country and in a given time in history.

According to Grize (1996), the mathematical logic is not concerned with the assertive subject. It makes the true and the false be in the nature of things as if the propositions were given. For him the natural logic cannot satisfy itself viewing this. Thus, the natural logic is not only object logic but equally a subject logic, more precisely the one with subject announcers who engage, assume a determination and interpret it. We will now briefly emphasize the discourse operations which refer to the subject enunciator.

The **turn polioperation** is an operation that, when applied in a judgement content, does not produce a simple proposition, but an expression, marking: (a) the enunciator subject (I, somebody, the scientist etc.); (b) its thought activity (to say, to believe, etc); (c) its time-space localization; and (d) a modality *de dicto* (establishing a judgement that the enunciator makes of what he refers to).

It is called **configuration** the structure of statements that gives meaning to the relationships between them. The configuration reflects the representation structure that the enunciator shows. In this sense, the mathematics formal logic connectors are used to establish an order for the different enunciations.

1 Method

In order to analyze the conceptualization process, we decided to perform a case study with 7 children (ages 10-12) from a public school in Brazil. The study was based in accompanying and helping the development of a research project of their own, based on a question they chose. For this, we had bi-weekly meetings, 2 hours and a half long, in which the children were able to research and write about their work. We asked them to build concept maps at the beginning of their projects, and then periodically (in a somewhat regular interval) review and update those maps in light of their research progress. In total, there were 25 meetings, and each participant was able to build 5 versions of their concept maps.

The data was obtained from the concept maps, and from the text written by the individuals in digital means: (a) in blogs- virtual agendas; (b) in the digital conceptual maps (built in CmapTools software), saved and shared in the internet in a server; and (c) in a wiki, an online system of electronic editing of internet pages. Moreover, the researchers made interviews (using Piaget's clinical method) after each different versions of the concept maps built by the subjects. Not only the data, but also the analysis performed are being organized in a digital database, projected and implemented in order to allow future studies to validate the model we now present.

Our follow up proposal of the conceptualization processes consists of the analyses of the logic operations (interpropositional operations, meaning implication levels and discursive logic operations), of a temporal series of data of the same subject which include speeches in natural language (obtained from the stored texts in the blog or in the wiki, as well as the transcription of the interview performed regarding the concept mappings) and propositions and systems of explicit relationships in the different versions of the concept maps that were built.. We will now demonstrate the application of the follow up model using the data of a single youngster: HEN (12 years old), whose research question was "how does a motorcycle engine work?". All the data presented refer to the speeches, written text and concept maps of HEN. The excerpts in italics are the original transcripts of such data.

5 Results

08/23/2005, interview – HEN [About the movement of the motorcycle]: *But there is a part that is in the engine, for example, like this, I don't know where it is, that I think makes it run. Put some gas, it is the food of that stuff, it would be a…some gears, it starts to spin like a bike peddle, so it would give power* [for the engine to run].

The first part, a transcript of HEN's speech on the first day of the project activities, reveals the available system of meanings regarding his hypotheses about the functioning of a motorcycle engine. In this extract, the same class-object is denominated part, stuff and then gear (retake operation). The logic-discursive operations, according to the configuration established by the subject, account for: locating the part in the engine (even though not precisely); marking the qualities of such part (to make the motor run - operation over the bundle); establishing a metaphor (gasoline -> food); and revealing the enunciator's thought operation (I think). Regarding the logical propositions effectively expressed, we initially have that "the part makes the engine run". There is an indication that the gasoline is responsible for the spinning of the referred part and that this movement implies in the necessary strength for the engine to run. But that still doesn't reflect a coordinated set of propositions, as the relationship system detailed by HEN in his first map (Figure 1), made using CmapTools software (Cañas et al. 1999; Cañas et al. 2004), has revealed.

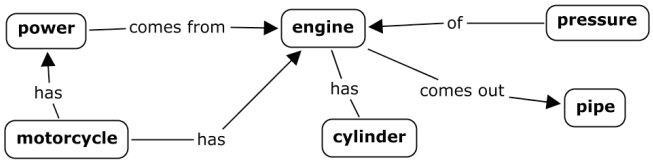


Figure 1. Part of the first concept map constructed by HEN on August 30, 2005.

In HEN's first attempt to formalize a representation of his knowledge, we observe a logical system that can be characterized as composed of local implications. The concept map describes the concepts that appear there based on its attributes (pressure of engine), components (engine has cylinder) or characteristics (power comes from engine). However, we can already observe that HEN, by an operation expressed in the combination of propositions, seems to indicate that the functioning of a certain system - the engine - results in the attribution of a 'new' characteristic to another system – motorcycle - to which the first one is subordinated (by a logic fitting): the motorcycle has power that comes from the engine. Is this a first sketch of systemic implications?

09/06/2005, interview - HEN: *You put gas (...) Makes, starts combustion, starts to burn, so with this burning there is pressure, this pressure goes to the cylinder, lowers the thing that I don't remember the name, so the…a kind of gear comes down and makes a crown comes up, let's say, like a bicycle, so in this crown there is a chain tied to the wheel, so with the spin of this crown the wheel starts to spin and the motorcycle starts to run*.

In general, the configuration of this excerpt doesn't establish internal elaborations to classes-objects. The disposal of statements reveals a sequence of events (a functioning explanation), and the final result is the motorcycle movement. It is interesting to observe that HEN, when reflecting about his work in the map, brings new elements (new concepts: cylinder, combustion, crown, etc.) and inserts them in the discourse to the determinations already expressed previously (like: 09/06 - a kind of gear comes down and makes a crown comes up, let's say, type of bicycle…←→ 08/23 - some gears, it starts to spin like a bike peddle, so it would give strength). His new elaborations will only show up (and partially) in the second version of the map (figure 2).

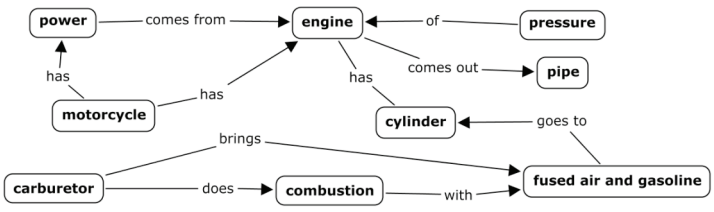


Figure 2. Part of HEN's second concept map, constructed on September 27, 2005.

The local implications of the first map now give place to a better differentiated system. We had already noticed, in our field agenda, on 09/09/2005 that HEN seemed to have reached the conclusion that it is necessary to have gas, the air and the sparkle produced by the spark plug (engine part) to have explosion. Our note, plus the previous excerpt of HEN's explanation about the first map, seems to be expressed by him in this sequence of propositions: "Carburetor brings fused air and gasoline, carburetor does combustion with fused air and gasoline, and fused air and gasoline goes to the cylinder". This novelty in the system provides more concrete evidences that HEN starts to make compositions between the propositions. Moreover, the links established by him expressed, besides the directly perceived observables, some cause and consequence relationships, as well as properties deducted from objects or actions (in thought) about them. Therefore, according to our classification, we have evidences of systemic implication systems.

10/04/2005, blog – HEN: *What is a carburetor? The carburetor is one of the most important parts of the engine, that's where the air meets the gasoline, and through this, the spark plug releases an electric discharge and with this discharge it gets on fire and explodes. What is spark plug (engine)? The spark plug is in the carburetor, it makes sparkles and with the sparkles, the explosion (combustion). What is explosion? Explosion is the same as combustion. And the explosion is formed by the fusion of gasoline and air. What is gasoline? The gasoline is a fuel that makes part of the combustion. What is a piston? It is a part that goes inside the cylinder. It is used to give pressure to the engine.*

This excerpt shows a new discursive elaboration by HEN, which results mainly from the examination of the second version of his concept map, as well as of the previous writings in the blog or wiki. Of importance here, to the logic-discursive operations, is the judgement of value (relevance criteria) of what is expressed: *carburetor is one of the most important parts of the engine*. The configuration shows a certain concern expressed by HEN in explaining recursively each term that appears in his text.

The last two concept maps that we are going to present and to discuss were constructed during the same day. For the construction of the first one, HEN followed strictly the method used in the previous versions: after a period of researching and discussing with his teachers and peers, he proceeded to the review of the last version available of his map and made all the modifications that he judged necessary. As it can be observed by the dates of each previous map, this period was approximately 30 days. The second map, however, resulted from the interventions done by an interviewer, during the clinical interview regarding the first section map (figure 3).

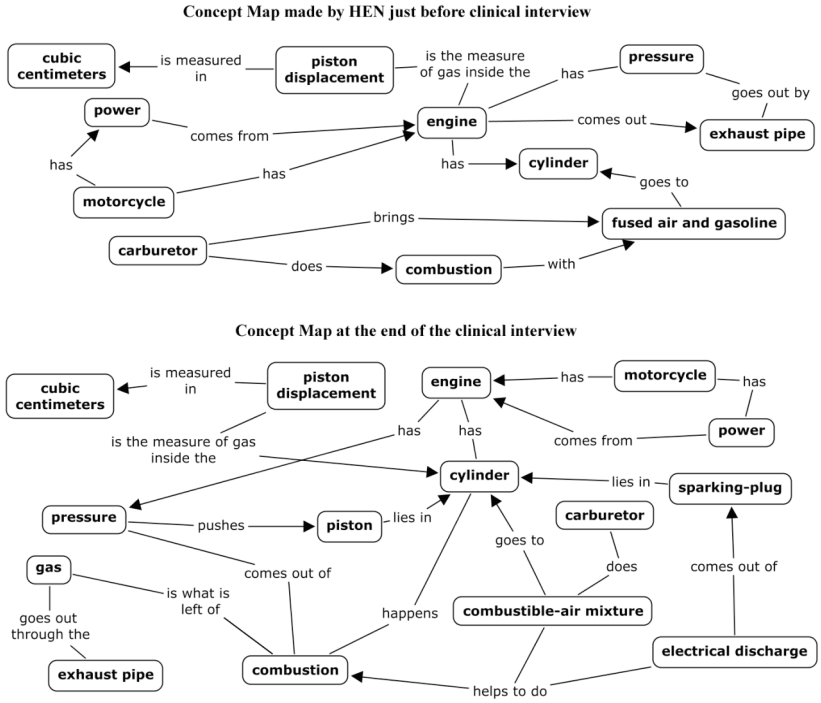


Figure 3. HEN's concept maps, constructed on November 4, 2005.

The first map of the figure 3, if compared to the previous version (Figure 2), reveals the modification on the phrase "pressure of engine, which is now "engine has pressure". That is, the pressure is no longer considered a motor quality to become a property, being incorporated to the domain of the motor functioning. It is also noteworthy that the differentiation of the "pipe" concept, which now appears as "exhaust pipe". The novelty is the presence of the propositions "piston displacement is the measure of the gas inside the engine", and "piston displacement is measured in cubic centimeters". This relationship system is still in the level of systemic implications. When we contrast the two maps of Figure 3, however, we notice that HEN has produced modifications in order to provide reasons and justifications. Or, as we said previously, he took steps towards answering questions like "how?" and "why?".

The strategy of this particular clinical interview consisted in asking for explanations regarding the relationships that appeared in the map at the beginning of the section. Immediately after each explanation given by Hen, he was asked to judge if his explanation could produce some kind of modification in the map and, if the answer was affirmative, he was encouraged to register it on his map (resulting on the second map of figure 3).

11/04/2005, interview- [What is this pressure?] HEN: *This pressure would be: the gases which were formed with the explosion, plus the gases which were not used for combustion. Because the oxygen and other gases get in and leave through the exhaust pipe. The explosion causes the pressure, which would be, let's say, a large volume of air that makes the cylinder move.* [How does that explosion occur?] HEN: *an electric discharge by the spark-plug so there is an explosion, and with this explosion there will be pressure, because it will push the cylinder. Because if there wasn't for that explosion, the cylinder wouldn't go down. (...) Combustion makes pressure.*

The configuration of the excerpt above shows a complex elaboration of the classes-object (not only internally, but in relation to other classes). Now, not only does HEN expresses the cause and consequence relationships, he already builds statements, and is able to build propositions that indicate a logic necessity: "*if there was not that explosion, the piston wouldn't go down"*. Indeed, the explanation given by HEN provoked the following modifications in the first concept map: (a) the concept "piston" was finally included, as well as the concepts "sparking-plug", "electrical discharge" and "gas"; (b) propositions were added, like "pressure pushes piston", "piston lies in cylinder", "pressure comes out of combustion", "electrical discharge comes out of sparking-plug", "gas is what is left of combustion" and "gas goes out through exhaust pipe".

At last, the following passage seems to reveal that HEN is effectively making logical operations with the propositions: "*potency and piston displacement ...the relation is that they measure something. The piston displacement measures the size of the cylinder and potency measures the engine power. They serve to measure things (...). The engine potency comes from the cylinder and what measures the cylinder is the piston displacement, so we say that there is a chain, right? It has a cycle*". Based on our criteria, he seems to be able to operate with conditions and justifications in the context of his research theme. We conclude, therefore, that there are evidences of structural implications at this stage of HEN´s discourse.

6 Summary

In contrast with a written text, the concept map seems to reveal itself more fertile in possibilities, in the sense of a more faithful expression of the system of meanings of an individual. In addition, it can be an excellent support device to conceptual construction and revision, as its structure allows for a different way to represent knowledge. It is important to remember, however, the dialectic aspect involving the two types of representation that we are analyzing: concept map and discourse in natural language. The construction of concept maps gives the opportunity to grasp levels of awareness, which influence the discourse configurations in natural language. In turn, the successive construction of discourses provides new elements for inferences, which can allow some new proposition combinations in the concept maps.

In this article, we presented and discussed the implementation of an analysis model which aims to follow up the conceptualization process through the analysis of natural language and periodically built concept maps. Based on theoretical constructs such as the *meaning implications* theory of Jean Piaget and Jean-Blaise Grize´s work in the analysis of *natural language,* we were able to produce results of the utilization of such model. The case presented here shows the conceptual differentiations established by an individual throughout his research project. We showed

that our analysis was able to identify evidences of his progress, based not only on the propositions expressed in his maps, but also on his speech and written text. In that way, we emphasize the relevance of taking into account these different types of data, and the longitudinal aspect of our study.

We believe that our theoretical approach, based on Jean Piaget´s Epistemology, provides a novel way to look at concept maps and its use as tools for learning evaluation. The analysis model presented here is a contribution for more deepened discussions, and aims to allow possible applications in the educational use of the concept maps. It is our intention to continue the investigation, as well as to establish partnerships in order to validate our analysis model.

References

Åhlberg, M. & Vuokko, A. (2004). Six Years of Design Experiments Using Concept Mapping – at the Beginning and at the End of Each of 23 Learning Projects. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Ausubel, D. P (2000). The Acquisition and Retention of Knowledge: a cognitive view. Dordrecht: Kluwer Academic Publishers.

Cañas, A. J., Ford, K.M., Coffey, J., Reichherzer, T., Suri, N., Carff, R., Shamma, D., Hill, G., Hollinger, M. & Mitrovich, T. (1999). Herramientas para Construir y Compartir Modelos de Conocimiento. In: 99 Workshop Internacional sobre Educação Virtual, Fortaleza, Brazil.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Arroyo, M., Carvajal, R (2004 CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Conlon, T. (2004). 'But is our concept map any good?': Classroom Experiences with the reasonable fallible analyser. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Cunha, M.J.S., Fernandes, E., Omar, C. T. & Silva, N. V. (2004). Avaliação de Aprendizagem Significativa Usando Mapas Conceituais num Ambiente Cooperativo. Diversidade e Integração: Desafios para a Telemática na Educação, XV Simpósio Brasileiro de Informática na Educação, Manaus, Brazil.

Dutra, Í. M., Fagundes, L. C. & Cañas, A. J. (2004). Un Enfoque Constructivista para el Uso de Mapas Conceptuales en Educación a Distancia de Profesores. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Grize, J. B. (1996). Logique naturelle et communication. Paris: PUF.

Novak, J. D. (1998). Learning, Creating, and Using Knowledge: Concept Maps(R) as Facilitative Tools in Schools and Corporations. Mahweh: Lawrence Erlbaum Associates.

Piaget, J. (1976). Ensaio de Lógica Operatória. Porto Alegre: Globo.

Piaget, J. & Inhelder, B. (1976). Da lógica da criança à lógica do adolescente. São Paulo: Pioneira.

Piaget, J. & Garcia, R (1989). Hacia uma lógica de significaciones. Cidade do México: Gedisa.

Piaget, J. (1996). Biologia e Conhecimento. São Paulo: Vozes.

Rocha, F.E.L. & Favero, E.L. (2004a). Linking Phrases in Concept Maps: A Study on the Nature of Inclusivity. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Rocha, F.E.L. & Favero, E.L. (2004b). A New Approach to Meaningful Learning Assessment Using Concept Maps: Ontologies and Genetic Algorithms. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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LOOKING FOR AN ALTERNATIVE STRATEGY FOR TEACHING AND TESTING: AN EXPERIMENT WITH CONCEPT MAPPING IN AN INCLUSIVE SCIENCE CLASSROOM

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He drew a circle that shut me out –
Heretic, rebel, a thing to flout.
But love and I had the wit to win:
We drew a circle that took him in.
EDWIN MARKHAM

1 Need for Inclusive Pedagogy

These beautiful lines express the whole philosophy of inclusive education and the place of concept mapping as a pedagogical option of educational setups in the near future. The last decade has seen many enormous changes in the philosophy of education. One of the greatest changes is the realization of the need for inclusive education and inclusive pedagogy. The concept of inclusion places emphasis on changing the system rather than the child. Inclusive schooling is often thought of as the inclusion of all students regardless of ability, into the same schools and classrooms with the peers who are not considered to have disabilities. Inclusive schooling extends far beyond mere physical proximity to providing students and adults the support required to belong and achieve in classrooms and school communities. Inclusion is both a process for and outcome of understanding, acceptance, and valuing of differences among today's school children and youth.

In response inclusive pedagogy is a term used to describe an emerging body of literature (Adams 1992; banks 19991; Darder 1996; Giroux & Mc Laren , 1996; hooks,1994) that advocates teaching practices that embrace the whole student in the learning process. Against this backdrop teachers are been called upon to teach students with a variety of needs and abilities.

2 The didactic role of concept maps in inclusive classrooms

During the process of learning, learning, learners construct a reality or an interpretation of reality based on their perceptions. Traditional conceptions of learning emphasize the object of our knowing rather than the process of coming to know what is actually learned. (Julio Valente da Costa Jr.) Constructivism, on the other hand, focuses on the mental processes inherent in the construction of meaning. These mental processes are highly dependent on the learner's prior knowledge, current mental structures, and existing beliefs (Jonassen et al. , 1993).

Adapting this to the process of learning in an inclusive classroom we, in our research wanted to help students with diverse abilities to get better control over the meanings of the surrounding that shapes their lives. We too, wanted the learning of science to be " conceptually opaque" (Novak 1991). For facilitating this type of learning, students need to see relationships and visualize the structure of content that they are studying.

Concept maps intend to represent meaningful relationships between concepts in the form of propositions. In order to provide opportunities for students to visualize the structure of content, we used concept maps as an instructional tool in an inclusive classroom.

Concept mapping is a technique for externalizing concepts and proposition (Novak 1990a). It exposes the concepts and the meanings that are hidden in the cognitive structure of students and it is of great importance since it helps the teacher and student to arrive at a shared understanding of content that is dealt with. It helps to clarify misconceptions and most often the superficial connections that are made in the teaching learning process. This is of much value in classrooms with a large number of students who vary in their abilities to make sense of the teaching learning experiences. Therefore while working with concept mapping technique, *one of the objectives*, was to

identify the difficulties, misconceptions and the superficial connections made by students while processing information from a given text matter.

There is a growing body of research that shows that when students work together in small groups and co-operate in striving to learn subject matter, positive cognitive and affective outcomes result (Johnson et al., 1981). In our attempt to understand how concept maps help students with diverse abilities to learn together we have tried to find out how working co operatively helps to bring together their own negotiations and construct their learning experiences. This is of great social value as it can help the students who are so differently abled to dialog, exchange, share and even sometimes compromise (Novak, 1984). *Secondly* this research paper is an attempt to see how students work together and negotiate while using concept maps as a tool for learning.

According to Novak and Gowin (1984), the process of teaching and learning has an emotional component too. Students when they construct new meanings and organize their own content, feel emotion. It is these emotions which will decide the course of the future learning (Dandekar 1999). The learner experiences this educative regularity called 'felt significance'. There are other emotions too like fear, which must be recognized and encouraged as an expression of 'felt significance' (Novak 1986). This brings us to the *third* objective of the research that is to understand the 'felt significance' experienced by students while they work together and construct new meanings and organize their own content.

3 Inspirational context for the use of Concept Mapping

A classroom of 75 students of standard VI participated in the study. The study comprised of a school that was located in the suburbs of the city of Mumbai. The students came from families that belonged to lower socio economic backgrounds, where they were the first generation learners with English not being their mother tongue but they were studying in schools where English was the medium of instruction. This could be due to the fact that English is considered as a ladder for social progress. These students were coming from socially, economically, educationally and linguistically deprived backgrounds. Apart from the above-mentioned deprivations a significant proportion of them also suffered from different kinds of disabilities like; speech impairment, visual impairment, besides there were twelve students who were recommended for certification as students with learning disabilities.

The fundamental challenge that we faced as we interacted with these students was in changing the locus of control in the teaching learning process from the teacher to the student due to traditional teacher centered mode of instruction, over emphasis on rote memorization and mechanical drilling, overcrowded classrooms and frequent absenteeism among the students that act as impediments in designing and implementing innovative teaching learning strategies.

These seventy-five students were further divided into seventeen groups. Each group had randomly allotted four to five students comprising of high, average and low academic achievers (based on their previous academic performance in the school's periodical tests), learning disabilities and physical impairment. Each group was provided with a mentor who was called '*Didi'* and '*Bhaiyyas'* which means elder sister and elder brother respectively. These mentors were trainee teachers of a college of education in the city of Mumbai and were allotted to that school for their practical trainee period .The role of the 'Didis' and '*Bhaiyya'* was to direct, encourage, facilitate and act as a 'sounding board' at times for student s to express their feelings during the learning process.

This project was conducted at three phases; comprising of three training modules.

i) Training of the mentors (ii) Preparation of the school students for the concept mapping activity. (iii) Introducing concept maps as an teaching learning tool for learning science subject which included the following topics-'Water' and 'Classification of Living Things' as given in the sixth standard text book. The sub themes of the topic 'Water' were; sources of water, properties of water and uses of water. The second unit contained classification of plants on the basis of height, presence and absence of flowers and life span and classification of animals on the basis of presence or absence of vertebral column and type of procreation. After a series of ten sessions with the students, they were assessed on their mastery of the content as well as the technique of concept mapping.

4 Experiences with Concept Mapping Technique

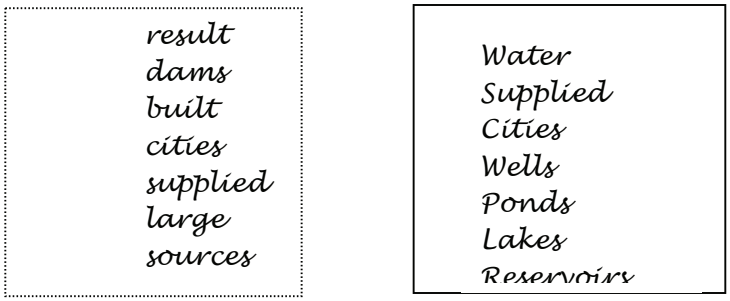
During our project with the students of standard VI at different sessions students had constructed various concept maps individually as well as in groups. The following are some of the maps and observations made by us at different stages in accordance with our research objectives that we set before us.

4.1 To identify the difficulties, the misconceptions an the superficial connections made by students while processing information from a given text matter while using the concept mapping technique.

During the second module ' Preparation of School Students for Concept Mapping Activity' and during the third module that is 'Using Concept Maps as a Teaching Learning Tool for Science Topics' the following difficulties were identified:

- Identifying the main concepts

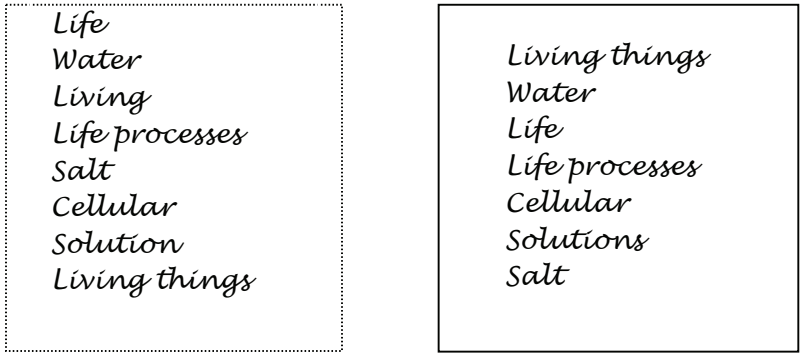
Based on a given content the students faced problems with identifying main concepts that the passage talked about. Here is an example of listed concept words for the content 'Sources of Water' by a student:



The words in the dotted outline boxes indicate the students responses while the other box indicates the desired responses. This was not only the problem with this particular student, but 48% of the students showed similar problems.

- Differentiating between the most general / most inclusive and most specific/less inclusive concepts.

For the sub topic' Importance of Water for Living Things' the students were asked to arrange the concepts in an order of most general to most specific. Example of listing of the hierarchical order of concepts as given by a student from a content passage in the text is given below.



Students expressed difficulty in organizing the concepts in the order of hierarchy or specificity, nearly 32% of the students showed the lack of ability to differentiate between most general to most specific concepts. This could be the result of a tendency to blindly copy the matter from the textbook. Students with linguistic backwardness were found to make mistakes even while copying and listing concepts from the text matter in front of them. This tendency to copy the text unquestionably was particularly found when students worked alone rather than in groups. Figure 1 is a concept map of Athesham, a student who was rated as an average achiever.

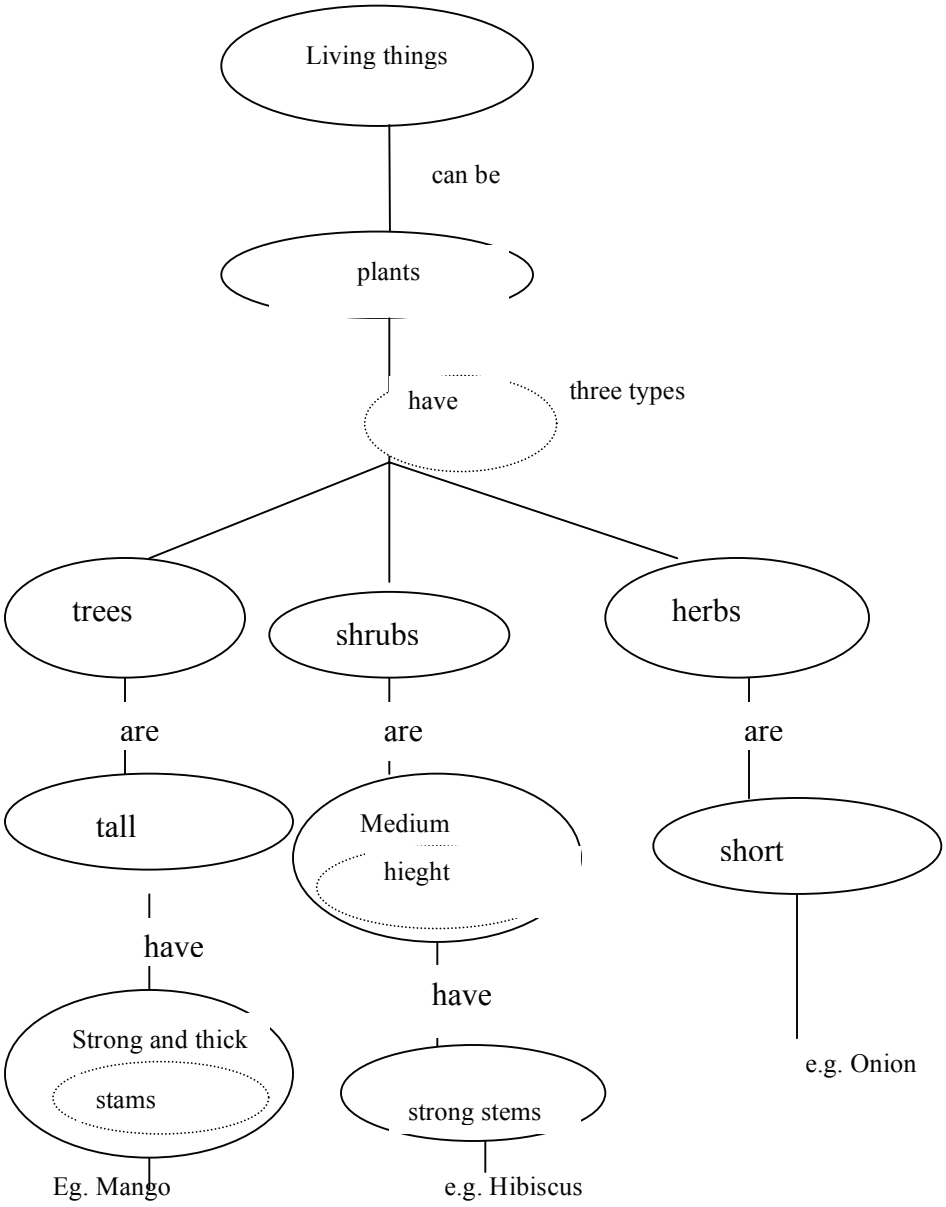


Figure 1 is a concept map of Athesham, a student who was rated as an average achiever by the schools. Words encircled in dotted lines indicate inappropriate language mastery or connections made by the student.

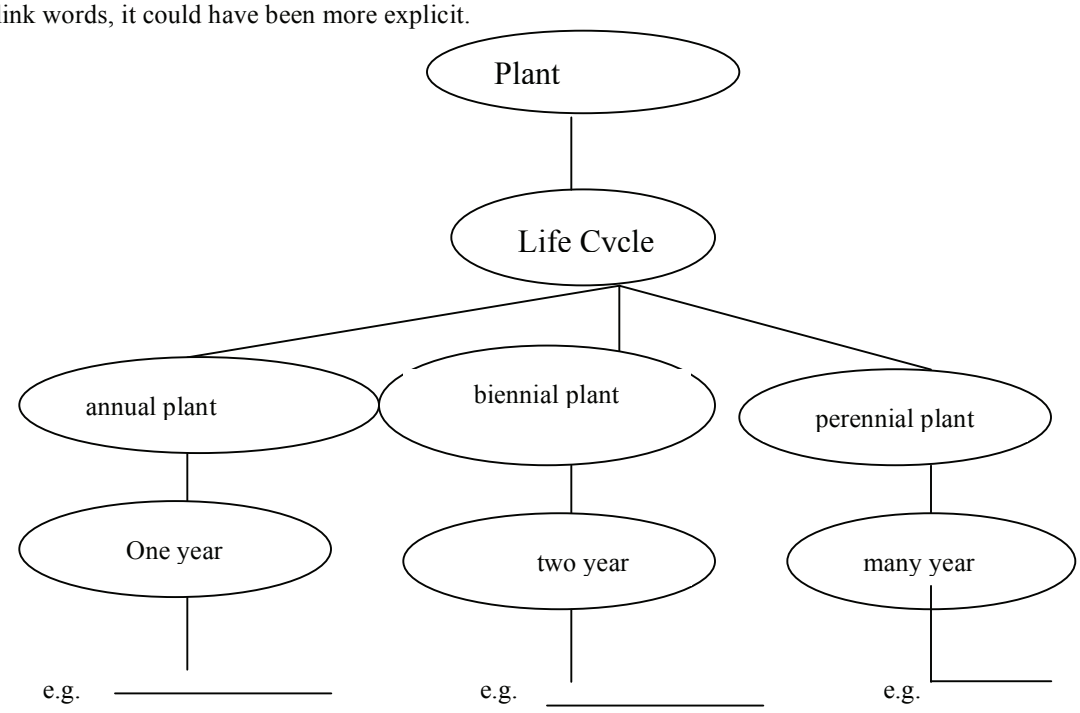
From the map it was evident that he associated the attribute tall with trees, medium height with shrubs and short with herbs. However the lack of an ability to subsume broader, more inclusive concepts with progressively more specific, less inclusive concepts below was evident .It was also evident that the lack of mastery over the language had come in the way of the organization of content.

- Identifying appropriate link words

The aspect of learning that is distinctly human is our remarkable capacity for using written or spoken symbols to represent perceived regularities in events and objects around us (Nowark & Gowin 1984). An awareness of the explicit role language plays in the exchange of information is central to understanding the value and purpose of concept mapping and educating. This was very much a part of our experiences in training students in concept mapping who were linguistically disadvantaged with regard to written and spoken English. The kind of link words that were often reflected in the connections made were*; is, an, as, has, have, the, of, on etc*. They found it difficult to

incorporate other verbs as link words. Besides sometimes student's concept maps were schematic representation of the content but were without any link words.

Figure 2 is an example of a map prepared by Devidas, an average achiever with speech impairment for the content based on the sub unit 'Classification of Plants on the Basis of Life Cycles'. This map was prepared individually. It is a reflection of content being classified, however with little more efforts in the use of appropriate link words, it could have been more explicit.



A shown in the above figures, and based on oral assessment, it was found that concept maps were not full reflections of their abilities to process and organize matter due to their lack of language mastery and learning habits. As stated earlier one of our challenges while working with these students was to help them to educate themselves and be responsible for their own learning. The technique had definitely contributed to self-study habits of the students as they were they were able to organize information even from unfamiliar content. The skill of organizing and presenting information was very evident in the high achievers. In figure 2 Devidas too, on oral questioning was able to present matter very logically but in different situations avoided the use of many words. This could be attributed to the speech impairment that he had.

4.2 To understand how students work together and negotiate while using concept maps as a tool for learning.

Over a period of years, in our experiences both at school and post graduate level, we have seen that in large class rooms it becomes very difficult to provide learning environments where students work together with peers in the social construction of personally significant meanings. The students in groups with their roles of facilitator, time keeper, recorder, material manager and spokesperson were more confident while working together rather than while working alone. Especially session 3 to 7 provided lot of opportunities for students to construct and build their understanding on topics like' Water' and 'Classification of Living Things'. Focusing on how different students process the information differently based on their abilities and disabilities we would like to present the map prepared by Khan Mohd. Aquib a student with vision impairment. This map was prepared by him on a small piece of content on the sub topic 'Uses of Water'

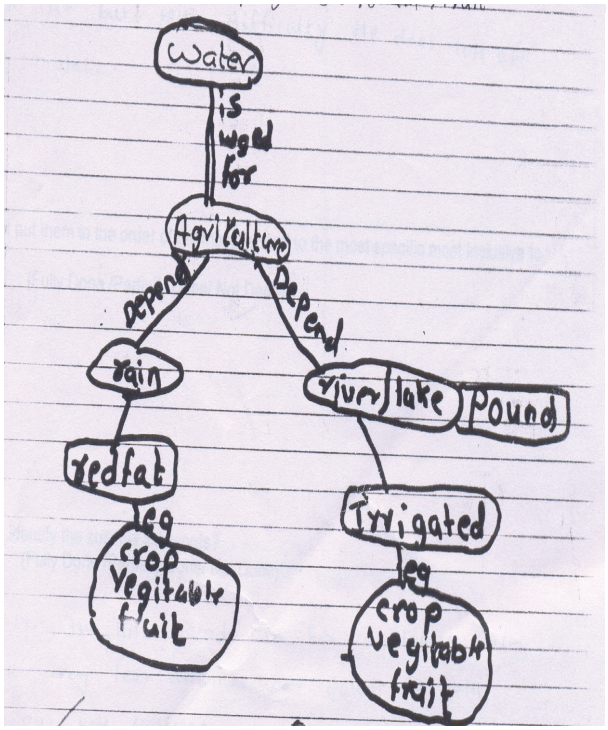


Figure 3- Concept Map prepared by Khan Mohd. Aquib on the sub topic 'Uses of Water'

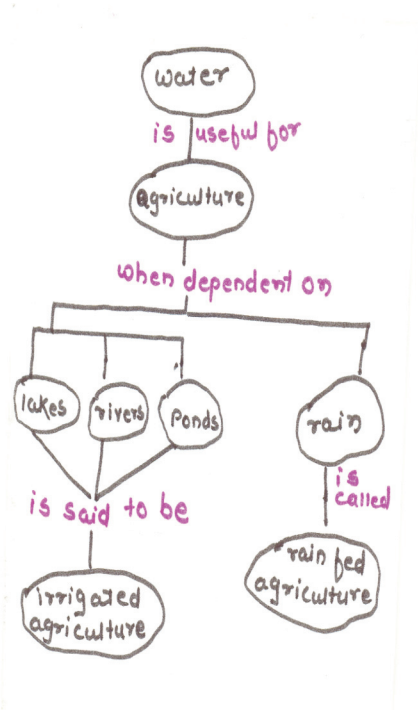


Figure 4- Concept Map presented by Khan Mohd. Aquib as a spokesperson for the group

The inability to express the ideas in a lexical form is evident. This however had not come in the way in which he processed and organized information. When Khan Mohd. Aquib worked with his peers in the group and then as the spokes person of the group, he was asked to present the concept map before the class. He presented the concept map as shown in figure 4, only due to the support and encouragement that he received from his group members.

Similarly, Figure 1 and 2 were combined as two groups dialoged, negotiated and shared their own understanding; they came up the following concept map that is given in Figure 5.

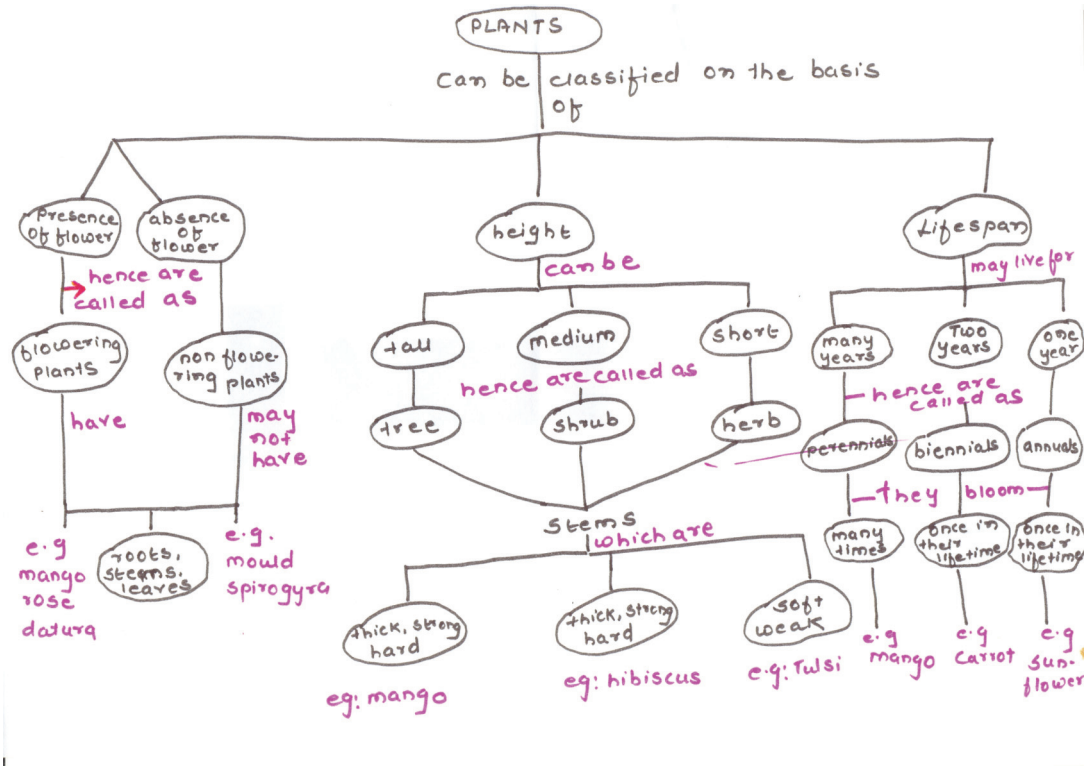


Figure 5. Concept Map prepared by two groups together on the topic 'Classification of Plants'.

As seventeen different groups worked together and co operated in striving to learn the subject matter, a positive cognitive and affective outcome was observed. There were evident features of affective outcomes that were visible in the group work and group presentations. Based on the daily observations and reflections of the mentors along with the unstructured interviews of the learners, the following are some of the affective and cognitive outcomes of learning.

There was a strong sense of bonding and "we feeling" among members of the same group. The above average student found fulfillment in providing suggestions for the organization of content in the concept maps. The below average students felt a sense of "equality" which made them feel responsible for their contribution to the group. It provided scope for a lot of creativity and diversity in the style of presentation both in the written and oral form. It developed a sense of confidence for oral presentation even though mastery over written mode of communication was lacking. It helped the average achiever to sharpen their cognitive competencies and information processing skills. The higher achievers morale was boosted and it gave them an opportunity to respect students who were differently abled in their group. This is how the concept mapping activity facilitated co operative learning essential for creating inclusive environment in the classroom .

4.3 To understand the 'felt significance' experienced by students while they worked together and constructed new meanings and organized their own content.

Based on the daily observations and reflections along with the unstructured interviews of the learners the following are some of the feelings of the students at different points of time while learning the technique and working in groups for the project.

I feel it helped me in learning how to make summaries for the lesson that I learn, I feel it help me in developing relationship between concepts, I feel I need not be worried about so many words and spellings while presenting my ideas, I feel confident of learning independently, I feel that I too am capable of understanding and learning science	*I feel scared of making big maps, I feel confused when I am asked to make cross links, I feel one needs good command over the language to use concept mapping as a tool for learning, I feel lost when I am to make maps for large content matter.*

These valuable feelings are representative of the entire class irrespective of diverse abilities among the students. These experiences give us a reason to celebrate a sense of achievement that results when students and teachers share meanings and give emotional support to one another leading to appreciate the diversity that exist within any classroom

5 Conclusion

This research project has left a deep impact on the researchers as well as the mentors involved in it. Along with the significant impact on the scholastic profile of the learners, concept mapping technique proved to be an effective alternative teaching and testing strategy for the inclusive science classroom. Though the experiences were varied and all could not be captured in this paper but this technique has provided and will provide a promise for making inclusion a reality. 'A road is made by walking' and so in our journey towards inclusion, concept mapping has helped us to cherish, appreciate and celebrate the diversities among the learners.

6 Bibliography

Aggarwal, J. C. (2004). Psychology of learning and development. Delhi: Shipra Publications.

Aggarwal, J. C. (2004). Child development and process of learning. Delhi: Shipra Publications.

Bhatnagar, A. B.; Bhatnagar, Meenakshi; Bhatnagar, Anurag (2003). Educational Psychology. Meerut: R. Lall.

Dash, M., & Dash, Neena (2003). Fundamentals of Educational Psychology. New Delhi: Atlantic.

Hardman, Michael, Drew, Clifford; Egan, M. Winston. (1999). Human Exceptionality: Society, school, and family. Boston: Allyn and Bacon.

Jayaswal, Sitaram (2002). Advanced Educational Psychology. Agra: Vinod Pustak Mandir.

Mathur, S. S. (1996). Educational Psychology. Agra. Vinod Pushtak Mandir.

Nakra, Onita (2003). Children and Learning Difficulties. New Delhi: Allied.

Novak, J. D., & Gowin D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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LOS MAPAS CONCEPTUALES COMO RECURSO PARA REPRESENTAR Y ANALIZAR BUENAS PRÁCTICAS DOCENTES EN LA EDUCACIÓN SUPERIOR

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Abstract. El conocimiento de expertos, en este caso de profesores universitarios definidos como "buenos docentes", puede extraerse a través de la utilización de mapas conceptuales. En este artículo se presenta el proyecto que están llevando a cabo 6 universidades españolas para visibilizar buenas prácticas docentes en las distintas especialidades. En él se han definido criterios de identificación de lo que son "buenas prácticas" y a través de entrevistas de "elicitación de conocimiento" y de grabaciones de sus prácticas docentes se ha ido recogiendo información sobre sus experiencias personales, ideas y opiniones sobre la docencia universitaria en general y la suya en particular. El CmapTools ha permitido representar toda la información de modo organizado, elaborando modelos de conocimiento de nuestros profesores y estableciendo relaciones entre las creencias y las prácticas. Además se ha utilizado como soporte en la elaboración del material multimedia de referencia. Este paper presenta uno de los casos analizados, el de una profesora de la carrera de Veterinaria con 21 años de docencia y un premio a la innovación docente.

1 Introducción: El Proyecto Visibilidad

Un grupo de investigadores de 6 universidades españolas están llevando a cabo, desde hace dos años un proyecto de investigación sobre "*Elicitación y representación del conocimiento de profesores universitarios protagonistas de "buenas prácticas docentes": ingeniería del conocimiento para la mejora de la calidad de la docencia universitaria en el marco del proceso de convergencia europeo"*. Lo denominamos Proyecto Visibilidad, porque ése es su propósito principal: visibilizar buenas prácticas docentes en la Educación Superior.

El citado Proyecto de Investigación se centra en dos aspectos fundamentales:

a) ¿Qué piensan los docentes universitarios que desarrollan "buenas prácticas" sobre la enseñanza?; ¿sobre qué ideas, creencias, percepciones fundamentan su "buen hacer docente"?; ¿cómo reconstruyen lo que han ido aprendiendo a través de su experiencia profesional?;

b) ¿En qué forma y bajo qué modalidades de representación podrían expresarse toda su experiencia y conocimientos de forma tal que pudiera servir como ejemplificación y marco de referencia para la mejora de la calidad de la docencia universitaria dentro del proceso de convergencia hacia un Espacio Europeo de Educación Superior que afrontan en la actualidad las universidades españolas?

Las mencionadas universidades españolas, en colaboración con el Florida Institute for Machine and Human Cognition (IHMC) estudiarán la visión de la enseñanza y la actuación didáctica de más de un centenar de profesores/as universitarios, seleccionados por sus "buenas prácticas" de todas las áreas científicas y profesionales de la Educación Superior. El proyecto ha sido seleccionado dentro de la convocatoria nacional para investigaciones de I+D+I promovida por el Ministerio de Educación español y tendrá una duración de 3 años.

La investigación incluye el establecimiento de ciertos criterios de identificación de lo que son "buenas prácticas" en la enseñanza universitaria. En función de dichos criterios se han seleccionado una muestra de profesores de distintas áreas y especialidades. Muestra que se irá ampliando progresivamente a lo largo de los tres años que dura la investigación. A través de entrevistas de "*elicitación del conocimiento"* se han ido recogiendo sus ideas y percepciones sobre la enseñanza y sobre sus propias prácticas. Esa información es, posteriormente, representada en mapas conceptuales.

La investigación incluye, también, la realización de grabaciones que recogerán secuencias significativas de las prácticas docentes de dichos profesores/as. En una entrevista posterior se recogerá el significado personal que cada docente atribuye a las prácticas grabadas.

El proyecto incluye la representación de las ideas básicas del profesorado participante en un mapa conceptual informatizado (en la línea de las modernas técnicas de ingeniería del conocimiento) que permita su visión de conjunto y el establecer la relación existente entre elementos de las creencias y las prácticas. Utilizamos, con este propósito el CmapTools (Cañas et al, 2004).

Los análisis de mapas y grabaciones se realizarán a tres niveles complementarios: análisis intra-sujeto (para identificar las ideas y prácticas propias de cada uno de los docentes participantes); análisis por grupo de especialidad (para establecer los patrones básicos de la cultura de cada gran especialidad- humanidades, ciencias sociales y jurídicas, ciencias experimentales, ingenierías, ciencias de la salud-, si los hubiere); análisis global del conjunto del profesorado a través de los tópicos centrales aparecidos (para identificar los factores básicos que configuran el pensamiento y las prácticas, y la relación entre ambos, de los docentes universitarios actuales).

Aparte del Informe Final, con los resultados de los análisis mencionados, el proyecto ofrecerá entre sus productos un DVD por cada uno de los profesores/as participantes de forma tal que pueda servir como punto de referencia para el profesorado novel que ingresa en la universidad y para otros profesores que deseen revisar su propia docencia.

2 La identificación y representación de las buenas prácticas docentes en la Educación Superior

Que la Universidad está cambiando es, en la actualidad un lugar común. La profunda modificación de las coordenadas políticas, sociales, científicas y técnicas en las que se mueven las universidades y la necesidad de acomodarse a las nuevas demandas de formación que se le plantean ha sido repetidamente mencionada en las sucesivas declaraciones de Bolonia del 1999, Praga 2001, Graz 2003 y Berlín 2003 como uno de los referentes básicos del proceso de convergencia hacia un *Espacio Europeo de Educación Superior* (EEES).

Una de las dificultades básicas para la mejora de la docencia en la universidad tiene que ver con su carácter de *actividad solitaria* ("*teaching as a lonely task*") que es llevada a cabo con un alto nivel de *discrecionalidad* ("privately owned"). Como consecuencia, la docencia universitaria se constituye en una realidad opaca y mal conocida. Se sabe poco de cómo actúa el profesorado universitario en el ámbito de su actuación docente real. Así como la investigación se desarrolla necesariamente en un espacio abierto y se nutre de interacciones y cruces de influencias y aportaciones, la docencia permanece en un territorio privado y discrecional. Es por ello que, al menos en el contexto español, esa mejora cualitativa de la docencia universitaria exige romper la inercia y la privacidad de la docencia universitaria y hacer "visibles" tanto las ideas como las prácticas de los docentes universitarios. De ahí el nombre de este proyecto: VISIBILIDAD. Se pretende identificar y hacer visibles el pensamiento y las prácticas de "buenos docentes" universitarios de manera tal que se haga posible el debate didáctico y pueda servir, además, como referente (*benchmaking*) para que otros docentes puedan analizar su propia práctica y, de ser preciso, reajustarla.

Como han señalado numerosos autores (Marton y Saljö, 1997; Trigwell y Prosser, 1996, 1999; Feixas, 2001; Bain, 2006) los profesores van madurando su concepción de la enseñanza a medida que van ganando en experiencia y en seguridad en su tarea docente. Se ha constatado, igualmente, que la actuación didáctica de los docentes viene condicionada por las ideas que profesan sobre la enseñanza (Quinlan, 1997; Bain, 2000) y que dicha visión influye efectivamente en el aprendizaje de los estudiantes (Trigwell, Prosser y Waterhouse, 1999).

3 Los mapas conceptuales

Explicitarlas ideas en las que los profesores y profesoras universitarias basan (consciente o inconscientemente) su actuación es una condición básica para transformar los procesos de enseñanza. Ha sido una idea permanente en la literatura especializada en innovación la necesidad de cambiar no sólo las conductas, sino también las ideas.Y para poderlas cambiar hay que conocerlas y ser capaz de penetrar analíticamente en ellas.

Con esa expectativa de mejora, las décadas de los 80 y 90 fueron realmente fértiles en investigaciones sobre el pensamiento de los profesores ("teacher thinking" movement). Aunque mayoritariamente los trabajos se centraron en el profesorado de los niveles básicos de la enseñanza (Marcelo, 1987; Zabalza, 1988), no faltaron tampoco trabajos relevantes, sobre todo en el contexto internacional, que entraron a analizar el "pensamiento de los

profesores universitarios" y la forma en que sus ideas sobre la enseñanza, el contenidos de sus materias, el aprendizaje de los estudiantes, etc. afectan a su forma de dar clase (Fox, 1983; Gow y Kember, 1993; Samuelowicz, 1999). Pasado aquellos años de especial dinamismo, el apogeo de esa orientación de la investigación pareció declinar, al menos en España, debido, sobre todo, a que se abordó desde una perspectiva excesivamente descriptiva y sin apenas compromisos con la mejora y el desarrollo.

En la actualidad, la aparición de nuevos recursos técnicos vinculados a la *ingeniería del conocimiento*, ha vuelto a revitalizar este planteamiento bajo nuevos enfoques y con mayores compromisos con la calidad. Situados como estamos en la *sociedad del* conocimiento, se trata, básicamente, de recuperar (y que no se pierda, que pueda ser utilizado por otros) el caudal de experiencia y competencias alcanzado por profesionales excelentes. De esta manera, las técnicas de *knowledge elicitation* y *knowledge capturing* están siendo empleadas por los Institutos de Investigación del conocimiento para preservar el conocimiento teórico-práctico alcanzado por los grandes profesionales de la medicina, la investigación espacial, la acción social, la dirección de empresas, la política, etc. (Cooke, 1994).

El ámbito de la enseñanza no ha quedado ajeno a ese movimiento (Herr, 1988) aunque, hasta el momento, España no ha entrado con fuerza en dicho proceso. Se trata, también en nuestro caso, de recuperar el bagage de experiencia y conocimientos de aquellos docentes a los que podríamos incluir en la categoría de "profesores excelentes". Trabajar con ellos, con lo que saben sobre la docencia de su materia concreta, supone un claro compromiso no sólo con la investigación básica (mejorar el conocimiento sobre la pedagogía universitaria) sino también con la investigación aplicada (aportar orientaciones bien fundamentadas para la mejora de las universidades y de los servicios que ofrecen). Como acaba de señalar Bain (2006: 13):

"*Me parece que la enseñanza es uno de esos entornos humanos que raramente se beneficia de su pasado. Los grandes profesores aparecen, pasan por la vida de sus estudiantes y sólo unos pocos de ellos quizás consigan alguna influencia en el vasto arte de la enseñanza. En la mayoría de los casos, su ingenio perece con ellos, y las siguientes generaciones deberán redescubrir de nuevo la sabiduría que dirigió su práctica. Como mucho perdurará algún pequeño fragmento de su talento, unas pocas piezas rotas en las que se encaramarán las siguientes generaciones sin llegar a ser plenamente conscientes de la riqueza existente bajos sus pies".*

El instrumento que vamos a emplear para propiciar esa visibilidad del pensamiento y la acción docente de los buenos profesores/as son los mapas conceptuales. Numerosos equipos de investigación nacionales e internacionales están empleando esta herramienta para identificar errores conceptuales (González e Ibáñez, 2000), para establecer los procesos seguidos por los alumnos en el aprendizaje de las diversas disciplinas (.....). Ha sido empleado, también en planteamientos similares a los nuestros, para reflejar los resultados del análisis de contenido de entrevistas (Hart, 1979, Hill& Michelson, 1981; Stark, S. et alii, 2002 de la Univ. de Washington: programa de terapia ocupacional). Su configuración basada en la relación explícita entre conceptos resulta muy adecuada para representar el conocimiento adquirido a través de la experiencia por los mejores profesores. A través de los mapas conceptuales nosotros pretendemos:

- Recuperar, analizar y establecer gráficamente de forma visible y comprensible el pensamiento científico-pedagógico y las prácticas didácticas (lo que piensan y lo que hacen como docentes) de una muestra de profesores/as de enseñanza universitaria caracterizados por desarrollar buenas prácticas docentes.

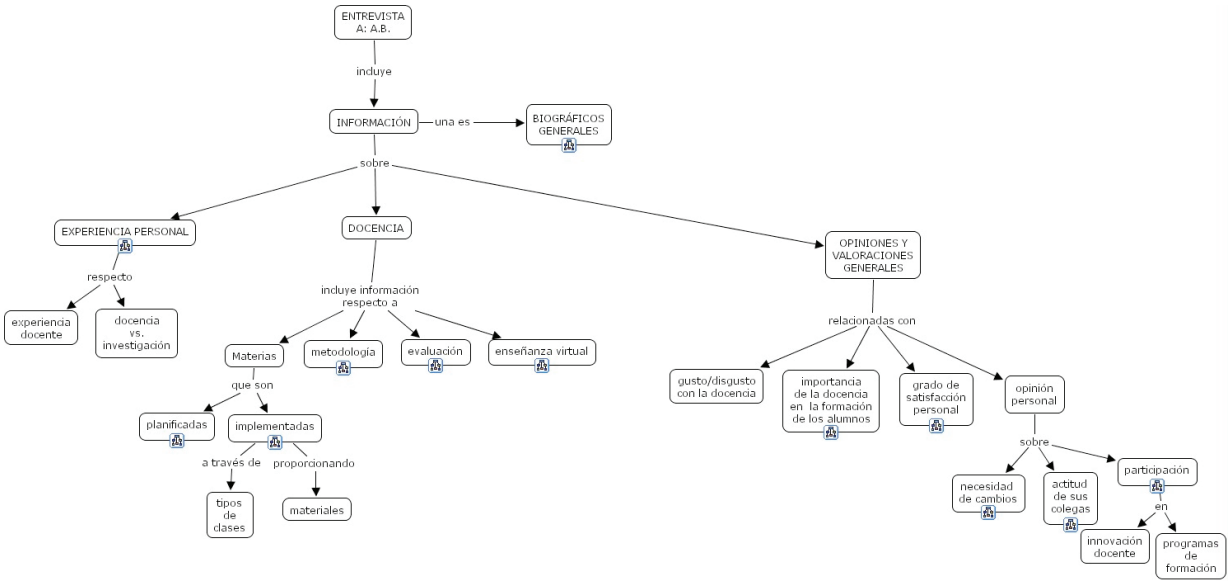
- Utilizar esas ideas y prácticas para definir, desde la vida real de las aulas universitarias estudiadas, los parámetros básicos de una "buena enseñanza" y ofrecer esa estructura como marco de referencia para la mejora de la calidad de la docencia universitaria y la formación docente del profesorado universitario.

4 El caso de Isabel

Isabel (nombre, obviamente, inventado) es una profesora de la carrera de Veterinaria. Tiene 44 años y lleva más de 20 como docente habiendo ocupado diversos cargos de responsabilidad en su Facultad. Enormemente implicada en la docencia y la investigación, ha sido seleccionada como profesora con "buenas prácticas" porque concurren en ella varios de los criterios establecidos: muy bien evaluada por sus estudiantes; promedio de resultados académicos de sus alumnos bueno, bien valorada por los colegas, comprometida con los procesos de innovación de la enseñanza.

Hemos mantenido con ella la entrevista inicial para intentar recuperar tanto su desarrollo personal y profesional en la docencia universitaria como sus ideas centrales sobre cómo ha de ejercerse la enseñanza y cómo la desarrolla ella misma. Hemos grabado, también, varias horas de sus clases. En este caso, se trata de clases de laboratorio en las que los estudiantes diseccionaban animales.

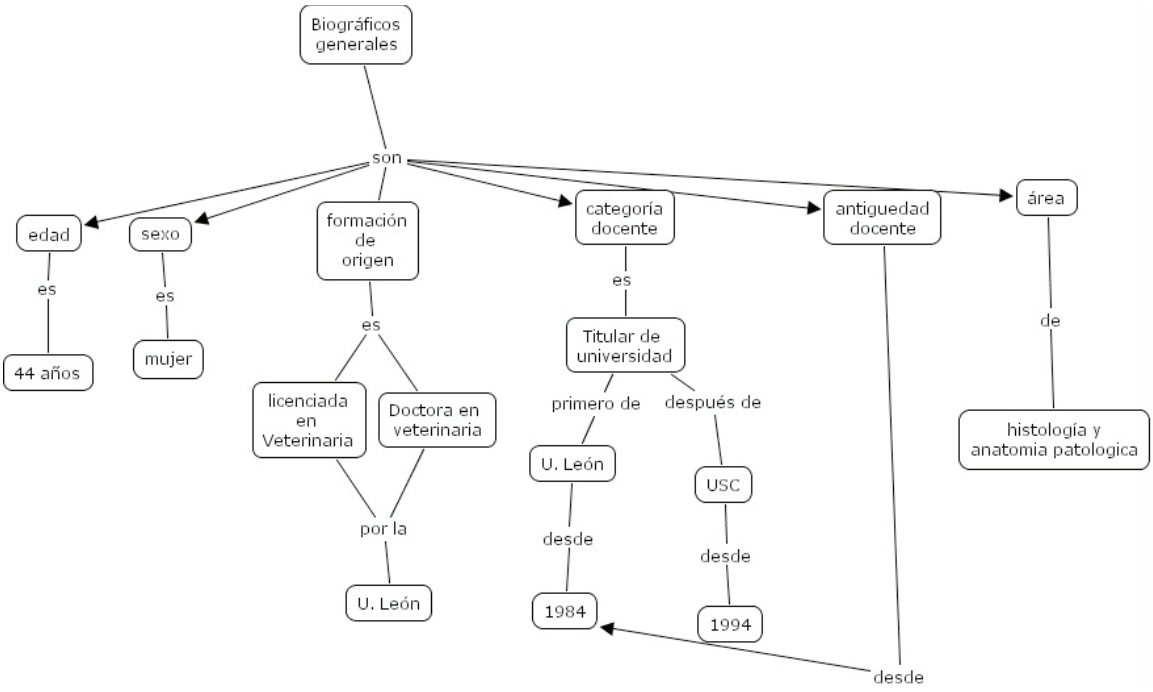
La entrevista está planteada en un formato semiabierto. Tiene una estructura básica claramente establecida pero las preguntas que se plantean a los entrevistados/as son suficientemente abiertas como para que ellos/as puedan orientarlas a su gusto. En resumen, se pretende obtener información sobre 4 grandes apartados: a) la biografía (para saber cómo ha sido su particular historia de vida y las diversas etapas por las que ha ido pasando hasta llegar a la etapa actual); b) su práctica docente desde los inicios hasta ahora (cómo enseñaba cuando inició su carrera profesional y cómo enseña ahora) tomando en consideración una serie de elementos básicos de la docencia; c) sus ideas, opiniones y valoraciones sobre aspectos clave de la docencia en la universidad ; d) su nivel de satisfacción con la tarea que realiza y sus resultados formativos.



Mapa 1: Modelo de entrevista

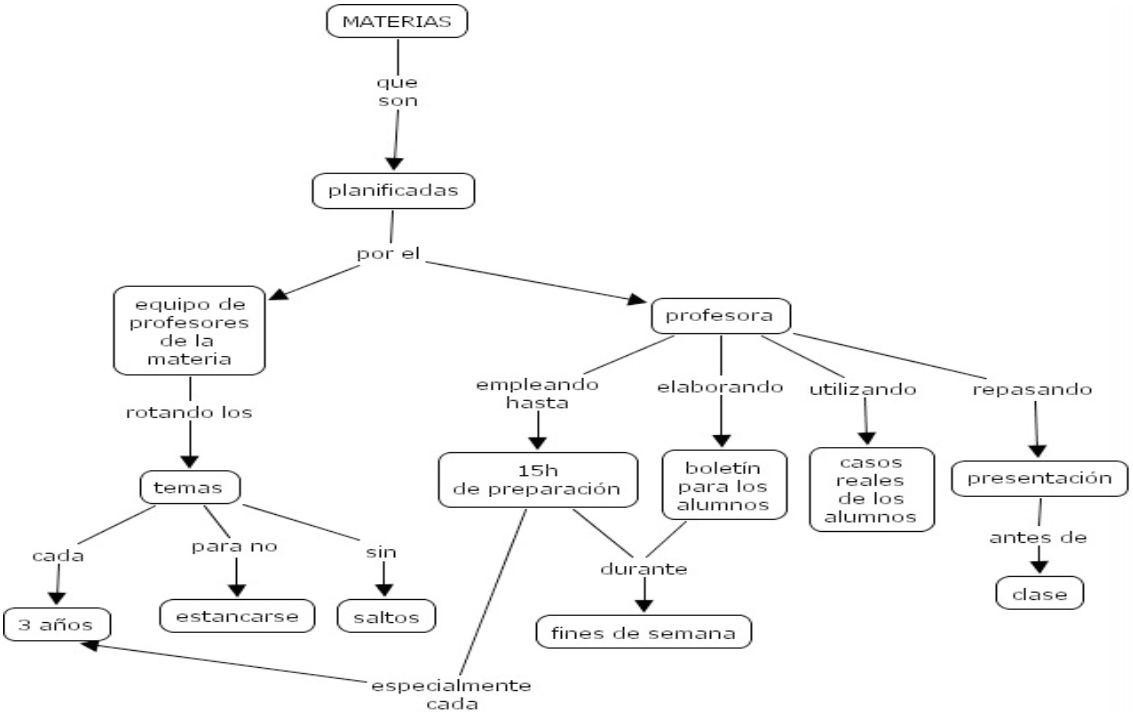
La información suministrada por esta profesora ha sido especialmente rica. Ha dado lugar, por tanto, a unos mapas conceptuales interesantes y claros sobre los *nodos* de su experiencia y su pensamiento, sobre cómo concibe la enseñanza y cómo plantea su desarrollo práctico. Aunque la gran riqueza de sus aportaciones resulta imposible de resumir en este corto texto, analizando el mapa conceptual de la entrevista (vide mapa 1) podemos constatar los siguientes elementos a destacar:

... la importancia de los comienzos de su vocación docente ya cuando era estudiante y actuó como "alumna interna" que colaboraba con los grupos de investigación de sus profesores y autorizaba a alumnos más jóvenes (vide mapa 2).



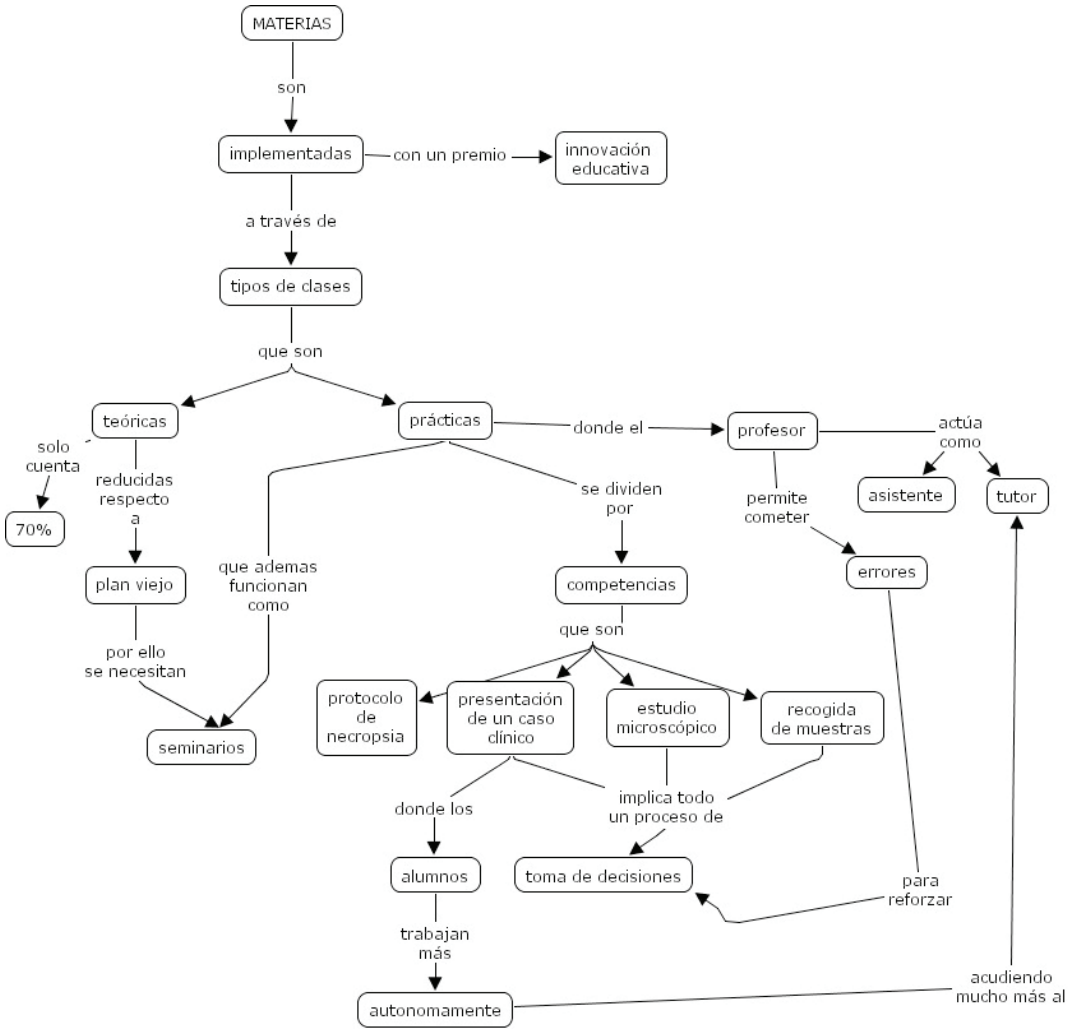
Mapa 2: Datos biográficos

... el trabajo en grupo de los profesores encargados de la materia que rotan en los temas cada tres años para no estancarse en una docencia rutinaria. Cada tres años ella prepara a fondo los temas que le toca desarrollar y dedica a tal fin un gran esfuerzo (de hasta 15 horas por tema). En esa fase la docencia predomina sobre la investigación (vide mapa 3).



Mapa 3: Palnificación de las materias

... el montaje teórico-práctico de la materia dando una gran importancia a las prácticas organizadas en tres semanas y que concluyen con la presentación de un caso clínico por parte de los estudiantes (vide mapa 4).



Mapa 4: Implementación de las materias

... la magnífica interpretación que hace del "aprendizaje autónomo" y "la toma de decisiones" por parte de los estudiantes (ellos deciden que fotografías tomar, qué muestras guardar, etc. y la profesora sólo sigue sus instrucciones aunque entienda que están equivocados)..

...su mención constante a que una buena docencia implica un notable esfuerzo por parte de los docentes. Un esfuerzo muy gratificante porque acaban constatando y admirándose el gran nivel de aprendizaje profundo que adquieren los estudiantes.

... su idea muy positiva de los estudiantes y de la Facultad.

...su concepción de la docencia como un proceso de motivación de los estudiantes para aprender y como una reducción de los contenidos a sus componentes más básicos, asequibles, y útiles para los futuros veterinarios. Ella entiende que cuando comenzó como docente era más exhaustiva (iba a los detalles pequeños, incluía la información más novedosa, etc.) pero que luego fue cambiando su idea y simplificando las cuestiones ("explico las cosas más claras, con menos palabras, huyendo al máximo de los tecnicismos... buscando lo más común... dándoles una base sólida en las cosas básicas...").

Bibliografía más relevante.

Bain, J.D. (2000): Celebrating Good Teaching in Higher Education. Puting Beliefs into Practice. En Bowie, C. (Ed.): Improving the Quality of Teaching for Learning. Brisbane: Queensland Branch of Higher Education Research and Development Society of Australasia (HERDSA).

Bain, K. (2006): Lo que hacen los mejores profesores universitarios. Valencia: PUV

Biddle, B.J.; Good, T.L. & Goodson,I.F. (2000): La enseñanza y los profesores I. La profesión de enseñar. Barcelona: Paidós.

Carlgren, I., Handal, G. & Vaage, S. (Edits. 1994): Teachers' Minds and Actions. Research on Teachers Thinking and Practice. London: Falmer Press.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cooke, N.J. (1994): Varieties of Knowledge Elicitation Techniques. *International Journal of Human-Computer Studies*, 41, 801-849.

Day, C., Calderhead, J. & Denicolo, P. (Edits, 1993): Reserach on Teacher Thinking: towards understanding professional development. London: Falmer Press.

Evans, L. y Abbott, I. (1998): Teaching and Learning in Higher Education. London: Casell

Feixas, Mónica (2002): Los cambios en la docencia del profesor universitario. Tesis doctoral. Dpto. de Pedagogía Aplicada. Universidad Autónoma de Cataluña.

Fox, D. (1983): Personal Theories of Teaching. *Studies in Higher Education*, 8: 151-163.

González, F. & Ibañez, F. (2000): Una aportación a la mejora de la calidad de la docencia universitaria: los mapas conceptuales. Pamplona: UPNA

Gow, L. & Kember, D. (1993): Conceptions of Teaching and Their Relationship to Student Learning. *British Journal or Educational Psychology*, 63: 20-33.

Herr, K. (1988): Exploring excellence in teaching: it can be done!. *The Journal of Staff, Program and Organization Development,* 6 (1): 17-20.

Hativa, N. y Goodyear, P. (Edit, 2001): Teacher Thinking, Beliefs and Knowledge in Higher Education. Dordrecht: Kluwer Academic Publishers.

Hornilla, T. (Coord. 1999): Formación del profesorado universitario y calidad de la enseñanza. Bilbao: Universidad del País Vasco..

Jiménez, A.B. & Correa, A.D. (2002): El modelo de teorías implícitas en el análisis de la estructura de creencias del profesorado universitario sobre la enseñanza. *Revista de Investigación Educativa*, vol. 20 (2).

Kember, D. (1997): A Reconceptualization of the Research into University Academics' Conceptions of Teaching. *Learning and Instruction*, 7: 255-285.

Kember, D. (2001): Beliefs about Knowledge and the process of Teaching and Learning as a Factor in Adjusting to Study in Higher Education. *Studies in Higher Education, 26 (2), 205-221.*

Kugel, P. (1993): How profesors develop as teachers. *Studies in Higher Education*, vol. 18 (3).

Marcelo, C. (1987): El pensamiento del profesor. Barcelona: CEAC.

Marton, F. & Saljö, R. (1997): Approaches to learning. En Marton, A.; Hounsell, D. & Entwistle, N.J. (Eds.): The experience of learning. Edinburgh: Scottish Academic Press.

Murray, K. & McDonald, R. (1997): The disjunction between lecturers' conceptions of teaching and their claimed educational practice. *Higher Education*, 33, 331-349.

Novak, J.D. (1998): Conocimiento y aprendizaje. Los mapas conceptuales como herramientas facilitadoras para escuelas y empresas. Madrid: Alianza.

Quinlan, K.M. (1997): "Case Studies of Academics' Educational Beliefs about their Discipline: toward a doscourse on scholarly dimensions of teaching. *Paper* presentado al Congreso Anual de la Higher Education Research and Development Society of Australasia. Adelaide, 8-11 Julio.

Robertson, D.L (1999): Profesors'perspectives on their teaching: a new construct and developmental model. *Innovative Higher Education*, vol. 23(4), 271-294.

Samuelowicz, K. (1999): Academics' Educational Beliefs and Teaching Practices. Thesis. Griffith University. Australia.

Samuelowicz, K. & Bain, J.D. (2001): Revisiting Academics' Beliefs about Teaching and Learning. *Higher Education,* 41(3), 299-325.

Singer, E.R. (1996): Espoused Teaching Paradigms of College Faculty. *Research in Higher Education*, 37: 659-679.

Stark, S. et alii (2002): Use of cognitive mapping to understand environmental characteristics that support social participation of individuals who have mobility impairments. Paper presented to the 130th Annual Meeting of APHA.

Sugrue, C., Day, C. (Edits. 2001): Developing Teachers and Teaching: International Research Perspectives. London. Falmer Press.

Trigwell, K. & Prosser, M. (1996): Changing Approaches to teaching: a relational perspective. *Studies in Higher Education*, 21: 275-284.

Trigwell, K., Prosser, M. & Waterhouse, F. (1999): Relations between Teachers' approaches to Teaching and Students' approaches to Learning. *Higher Education,* 37, 57-70

Wright, A. (Edit., 1995): Teaching Improvement Practices: successful strategies for Higher Education. Bolton, MA: Anker Publis.

Zabalza Beraza, M.A. (1988) : "Pensamiento del profesor y desarrollo didáctico", Enseñanza, nº 4-5, Pg. 109-138

Zabalza, M.A (1991): Diarios de Clase. Barcelona: PUP.

Zabalza, M.A. (2002): La enseñanza universitaria: el escenario y sus protagonistas. Madrid: Narcea

Zabalza, M.A. (2003): Competencias docentes del profesorado universitario. Madrid: Narcea

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

LOS MAPAS CONCEPTUALES EN LAS FASES DE APRENDIZAJE DEL MODELO EDUCATIVO DE VAN HIELE

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Resumen. El diseño de experiencias de aprendizaje de conceptos de un área del conocimiento es una tarea que requiere de bases pedagógicas y metodológicas que le ayuden a los profesores a encontrar las formas más eficientes de presentación de éstos a sus alumnos. En la enseñanza de conceptos matemáticos y geométricos el modelo educativo de van Hiele (van Hiele, 1957) ha sido de gran utilidad cuando se explora el nivel de razonamiento y la comprensión que adquieren los alumnos cuando son expuestos a diferentes formas de instrucción. El modelo esta constituido por tres (3) partes: los niveles de razonamiento, las fases de aprendizaje y el *insight* y son una guía que orienta el proceso de instrucción y evaluación. Las fases de aprendizaje ayudan a determinar las actividades que deben desarrollar los alumnos para potenciar la comprensión y el avance de un nivel de razonamiento al siguiente.
Se presentan los mapas conceptuales como una herramienta de exploración e integración para las fases de aprendizaje del modelo de van Hiele. Los resultados expuestos son el producto de una experiencia de aula, en la que se desarrolló un modulo de instrucción, que contiene experiencias de aprendizaje para el concepto de aproximación local en su manifestación de recta tangente a una curva plana en un punto dado sobre ella.

1 Introducción

En la enseñanza de conceptos matemáticos y geométricos se requiere que los profesores presenten a sus alumnos experiencias de aprendizaje que reten su imaginación y no se queden en la propuesta de ejercicios algebraicos, rutinarios y sin contexto que no les ayuda a progresar en su nivel de razonamiento. Las fases de aprendizaje del modelo de van Hiele son una forma de graduar la instrucción para ayudar a los alumnos a comprender los conceptos objeto de estudio en diferentes contextos con el objetivo de que ensanchen su estructura cognitiva y los puedan exponer a sus compañeros o así mismos utilizando el lenguaje natural, el lenguaje simbólico, la resolución y el diseño de problemas propios.

En el modelo educativo de van Hiele cada nivel tiene su propio lenguaje (van Hiele, 1957). Debido a esta característica, cuando se diseñan experiencias de aprendizaje con base en las fases de aprendizaje es necesario analizar el lenguaje empleado por los alumnos para referirse a los conceptos objeto de estudio. Es así, como en este aspecto, los mapas conceptuales guardan una estrecha relación con el modelo (Esteban & Vasco & Bedoya, 2004) y pueden implementarse en diferentes etapas de la instrucción.

En los últimos años de secundaria y en el primero de universidad se comienza a exponer el concepto de aproximación local que está relacionado con todos los procesos de paso al límite, tales como el de recta tangente a una curva plana en un punto dado sobre ella, el de derivada de una función en un punto, el de continuidad de una función en un punto, la convergencia de sucesiones y de series. La exposición se hace de manera intuitiva a partir de definiciones con palabras evitando la simbología necesaria que requiere un tratamiento riguroso. Es común creer que la compresión de los procesos en los cuales esta involucrado éste concepto no deberían presentar obstáculos para los alumnos. Por ello, se pasa rápidamente de las definiciones presentadas en forma verbal a los problemas algebraicos, sin tener en cuenta el razonamiento que es inherente a los conceptos que requieren el paso al límite.

En este artículo se presenta el diseño de un modulo de instrucción en base a las fases de aprendizaje del modelo de van Hiele para ayudar a progresar a un grupo de alumnos del nivel 2 al nivel 3 de razonamiento del modelo de van Hiele. El concepto matemático elegido durante la experiencia es el de recta tangente a una curva plana en uno de sus puntos, que es una manifestación del concepto de aproximación local. En cada una de las fases se exploró el lenguaje utilizado por los alumnos y la forma como su estructura cognitiva se iba ensanchando a través de los mapas conceptuales.

2 Marco teórico

El modelo educativo de van Hiele (van Hiele, 1957) se formuló inicialmente para la enseñanza y el aprendizaje de la geometría elemental. Esta compuesto por tres (3) partes: (i) El *insight,* definido como comprensión (van Hiele, 1986). (ii) Los niveles de razonamiento, describen la forma como los estudiantes asimilan y efectúan diversas actividades a partir de un concepto geométrico, el modelo determina cinco (5) niveles y de acuerdo con la nomenclatura utilizada actualmente (Llorens, 1994) se clasifican en nivel 0, predescriptivo; nivel 1, de reconocimiento visual; nivel 2, de análisis; nivel 3, de clasificación y relación y nivel 4, de deducción formal. Los niveles de razonamiento no están asociados a habilidades computacionales o al desarrollo biológico del individuo, más bien están en función de las experiencias de aprendizaje a las que ha sido expuesto un individuo a lo largo de su vida con respecto al concepto objeto de estudio. Son jerárquicos y secuenciales, y por lo tanto una indicación de la gradación del razonamiento de un alumno a lo largo de las experiencias para la apropiación de un concepto. (iii) Las fases de aprendizaje, están orientadas a ayudar a progresar a un alumno desde un nivel de razonamiento al inmediatamente superior, básicamente las fases constituyen un esquema para organizar la enseñanza, son cinco (5) y se clasifican en fase 1, información; fase 2, orientación dirigida; fase 3, explicitación; fase 4, orientación libre y fase 5, integración.

En investigaciones recientes se ha extendido el modelo al Análisis Matemático, centrándose en la forma como razonan los alumnos frente al concepto de aproximación local en algunas de sus manifestaciones, como son: La tangente a una curva plana en uno de sus puntos (Llorens, 1994 & Esteban, 2000), la continuidad local (Campillo, 1999), la convergencia de una serie de términos positivos (Jaramillo, 2000), la modelización del espacio y del tiempo (De la Torrre, 2000) y la convergencia de sucesiones (Navarro, 2002). En estas investigaciones se tenía como uno de sus objetivos determinar el nivel de razonamiento alcanzado por los alumnos cuando son expuestos a los conceptos estudiados en forma magistral, es decir, cuando el profesor expone los conceptos con poca o ninguna participación de los alumnos y se evalúa su desempeño con pruebas cerradas.

En cada uno de los trabajos mencionados se diseñaron tests semi-estructurados[1] con el fin de detectar del nivel 0 al nivel 3 de razonamiento. De acuerdo con el modelo, se establecieron descriptores para cada uno de los niveles estudiados que permitían la detección de los mismos a partir de la actividad de los alumnos. Los descriptores y los tests aplicados a los alumnos se diseñaron a partir de entrevistas de tipo socrático, buscando que las tareas propuestas recogieran la relación existente entre un determinado nivel de razonamiento y el lenguaje propio de este, teniendo en cuenta que su aplicación debe privilegiar la detección de los niveles de razonamiento sin confundirlos con niveles de habilidad computacional o conocimientos previos. Un resultado concluyente de estas investigaciones es que solamente la cuarta parte de los estudiantes que asisten a clases magistrales están el nivel 3 de razonamiento, que es el que les permite avanzar con éxito en el estudio de las matemáticas universitarias que se fundamentan en el concepto de aproximación local en manifestaciones como las de límite, derivada e integral.

El diseño de módulos de instrucción[2] (Fuys & Geddes & Tischler, 1988) que tuvieran como base las fases de aprendizaje del modelo de van Hiele no se exploró en ninguna de las investigaciones referidas anteriormente. Teniendo en cuenta los resultados obtenidos, cabe preguntarse ¿Qué sucede cuándo se diseñan un módulo de instrucción a partir de las fases de aprendizaje del modelo y se aplica a estudiantes que están en el nivel 2 de razonamiento?, ¿será posible que un mayor número de estudiantes progresen al nivel 3?

2.1 Las fases de aprendizaje en el modelo de van Hiele y los mapas conceptuales

En el modelo de van Hiele el análisis del lenguaje empleado para expresar un concepto es fundamental para la adscripción a un determinado nivel de razonamiento, al punto que cada nivel tiene su propio lenguaje, por ello una herramienta que facilita el análisis del lenguaje en el modelo (Esteban & Vasco & Bedoya, 2004) son los mapas conceptuales, que permiten determinar las relaciones y de esta forma obtener un acercamiento a la estructura cognitiva que un alumno posee en relación a un concepto en el momento de la elaboración del mapa.

[1] Cada pregunta tenía cinco (5) opciones de respuesta, de las cuales en la última el alumno podía escribir la que considerara más acertada en el caso cuando ninguna de las anteriores le pareciera correcta.

[2] Un módulo de instrucción es una colección de actividades diseñadas con un objetivo específico.

En las fases de aprendizaje se busca que a medida que se van aplicando el estudiante reelaboré el lenguaje empleando con relación al concepto estudiado para que pueda progresar del nivel de razonamiento en que se encuentra al inmediatamente superior. Las fases de aprendizaje del modelo se definen de la siguiente manera:

- Fase 1. Información. Se explora mediante tests, entrevistas, gráficas o exposiciones realizadas por los alumnos. Con ello se busca que expliciten la información que tienen en su estructura cognitiva acerca del concepto objeto de estudio.
- Fase 2. Orientación dirigida. El profesor propone actividades en las que el concepto se relacione con situaciones de la vida diaria y anima a los alumnos para que encuentren sus propias relaciones, las compartan y discutan con sus compañeros.
- Fase 3. Explicitación. Los alumnos aplican el concepto para resolver problemas que correspondan a situaciones reales en diferentes contextos.
- Fase 4. Orientación libre. Se completa la red de relaciones que se comenzó a formar en las fases anteriores y se adquiere el lenguaje propio del siguiente nivel de razonamiento. Partiendo del concepto estudiado y de sus propios intereses los alumnos deben formular y solucionar sus propios problemas.
- Fase 5. Integración. El concepto estudiado se reorganiza y adquiere un nuevo significado. Se hace explicita la nueva red conceptual y el conjunto de habilidades de razonamiento adquiridas.

Debido a que en cada una de las fases los alumnos deben elaborar actividades concretas y presentar sus avances los mapas conceptuales son una herramienta que permite analizar estas tareas a lo largo del proceso. De esta forma, el mapa que se elabore al final de una fase le servirá de guía al profesor para diseñar o ajustar las actividades de la siguiente fase, pues los mapas conceptuales ayudan a desarrollar entre otras las siguientes destrezas cognitivas: (i) "Las conexiones con ideas previas, tanto al inicio del proceso, como después de su conclusión", (ii) "La capacidad de inclusión, dada la jerarquización de los conceptos y el nivel que implica su relación", (iii) "La diferenciación progresiva entre conceptos" y (iv) "La integración de nuevos conceptos a través de relaciones cruzadas válidas entre ellos" (Novak & Gowin, 1999).

El concepto de tangente a una curva plana forma parte del currículo de los últimos años de la secundaria y del primer año de universidad en las carreras científicas y técnicas. Debido a sus propiedades geométricas, este concepto se puede estudiar sin recurrir a manipulaciones algebraicas o algorítmicas, por ello se escogió para el diseño del modulo de instrucción que fue puesto en práctica con un grupo de estudiantes que se encontraban en el nivel 2 de razonamiento del modelo de van Hiele para ayudarlos a progresar al nivel 3.

2.2 El concepto de aproximación local en su manifestación de recta tangente a una curva plana en punto dado sobre ella

La recta tangente a una curva plana en un punto dado sobre ella es una manifestación del concepto de aproximación local. Para su estudio, se puede dotar de una componente visual y geométrica como el mecanismo[3] del haz de secantes[4] que es el que se encuentra en todos los libros de Cálculo. Este mecanismo le permite al alumno realizar razonamientos en los cuales está involucrado el proceso del paso al límite y a la vez le ayuda a hacer explícitos las elaboraciones mentales que efectúa para obtener sus conclusiones mediante el lenguaje. El hecho de poder definir la tangente utilizando aspectos geométricos y no algebraicos "… fue lo que permitió extender el modelo de van Hiele al campo del Análisis Matemático, en particular al concepto de aproximación local, llevándolo fuera del ámbito de la geometría elemental" (Esteban, 2000).

El conjunto de descriptores determinados para adscribir a un alumno en uno de los niveles 0 al 3 (Esteban, 2000) se basan en el mecanismo del haz de secantes. Para el nivel 2 se propusieron dos descriptores de separación que son una guía para diseñar experiencias de aprendizaje que pueden ayudar a los alumnos a progresar al nivel 3, se enuncian a continuación:

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[3] Otro mecanismo es el zoom, que se obtiene al fijar un punto A sobre una curva plana C. La tangente, si existe en A, es la recta a la que "parece" tender la curva cuando nos aproximamos más y más dejando fijo el punto A.

[4] Dada una curva plana C y un punto fijo A sobre ella, se eligen puntos $P_1, P_2, \ldots P_n$, cada vez más cercanos por la izquierda o por la derecha de A. El conjunto de rectas que pasan por A y por los puntos $P_1, P_2, \ldots P_n$ forman el haz de secantes. La tangente en A, si existe, es el límite del haz de secantes.

- "El alumno no dará, en general, respuesta a las situaciones patológicas, es decir, aquellas en las que exista alguna dificultad para realizar el proceso de aproximación. Por ejemplo, para la recta y para los ángulos (valor absoluto). En este nivel, el mecanismo del haz de secantes no se tiene como un mecanismo para encontrar la recta tangente para todas aquellas curvas en las cuales se puede aplicar, presentándose desconcierto en las situaciones patológicas. No define la tangente a una curva en un punto a partir del haz de secantes y la capacidad de deducción de propiedades no se tiene aún desarrollada, estas son diferencias que marcan la separación entre los niveles 2 y 3 de razonamiento."

- "Un alumno no progresará desde el nivel 2 al nivel 3 mientras mantenga dualidades entre el concepto imagen (la progresión de las secantes que pasan por un punto *A* de la curva y por otros puntos situados sobre la curva cada vez mas cercanos a *A*) y el concepto definición (reconocer la tangente como el límite del haz de secantes, es un proceso infinito). El nivel de razonamiento que permite la compresión de los conceptos avanzados o dinámicos es incompatible con la dualidad entre concepto imagen y concepto definición. La plena integración entre los conceptos intuitivos estáticos (tangente a una circunferencia) con los dinámicos (aproximación infinita mediante el haz de secantes) caracteriza el acceso al nivel 3."

A partir de éstos descriptores queda manifiesta la importancia que tiene el lenguaje para la adscripción de un alumno en el nivel 2 de razonamiento y el progreso al nivel 3. Por lo tanto, las experiencias de aprendizaje que conformen el módulo de instrucción deben tener en cuenta la forma como los alumnos expresan los conceptos de punto, recta y curva involucrados para describir el de tangente. Por ello, los mapas conceptuales son una herramienta que ayuda desde el inicio de las experiencias a entender la estructura cognitiva y la evolución en el lenguaje que va teniendo un alumno a medida que el profesor pone en práctica el diseño en el aula de clase.

3 Los mapas conceptuales y su aplicación en las fases de aprendizaje del modelo de van Hiele

En este artículo solo se ilustran las actividades correspondientes a los mapas conceptúales en el diseño y aplicación de un modulo de instrucción basado en las fases de aprendizaje del modelo de van Hiele para ayudar a progresar a un grupo de alumnos del nivel 2 al nivel 3 de razonamiento en relación al concepto de aproximación local en su manifestación de recta tangente a una curva plana en un punto dado sobre ella.

Antes de comenzar con el análisis e interpretación de los mapas conceptúales presentados por los alumnos, se resalta el hecho de que ellos fueron instruidos en la elaboración de la técnica durante un periodo de dos semanas, con el fin de evitar errores en la creación de los mismos, ya que según Novak "algunas de las concepciones equivocadas puede que se deba simplemente a la falta de destreza con los mapas" (Novak & Gowin, 1999). Lo anterior buscaba que los alumnos realizaran mapas conceptuales más claros y sin el amontonamiento de conceptos para aumentar el grado de estructuración en la elaboración de los mismos.

Para lograr este propósito, se realiza el mapa conceptual expuesto en la Figura 1, denominado "mapa del experto", con el fin de implementarlo como guía del proceso académico de instrucción al que fue expuesto un grupo de alumnos (grupo experimental), dentro del proceso de investigación. Además, de utilizarlo como herramienta base para realizar el proceso de evaluación del lenguaje empleado por los alumnos después de concluida cada una de las fases de aprendizaje donde era requerida la implementación de la técnica. Para dicho mapa, los términos y conceptos base son el de punto, recta, curva, tangente, haz de secantes y aproximación local.

Las experiencias de aprendizaje diseñadas se aplicaron a 39 alumnos seleccionados de un total de 154 del primer año de universidad. Dichos alumnos fueron clasificados en el nivel 2 de razonamiento con la aplicación del test "Curvas y Tangentes" diseñado por Esteban (Esteban, 2000). La duración de la intervención pedagógica fue de 30 horas. Los alumnos restantes continuaron con la clase magistral en la que se trabajaban los conceptos propios del Cálculo.

A continuación se muestran cuatro (4) mapas conceptuales representativos del grupo experimental para cada una de las fases donde se requería la aplicación de la técnica. Estos muestran el progreso en el lenguaje de los alumnos de acuerdo con los descriptores de separación presentados para avanzar del nivel 2 al nivel 3 de razonamiento.

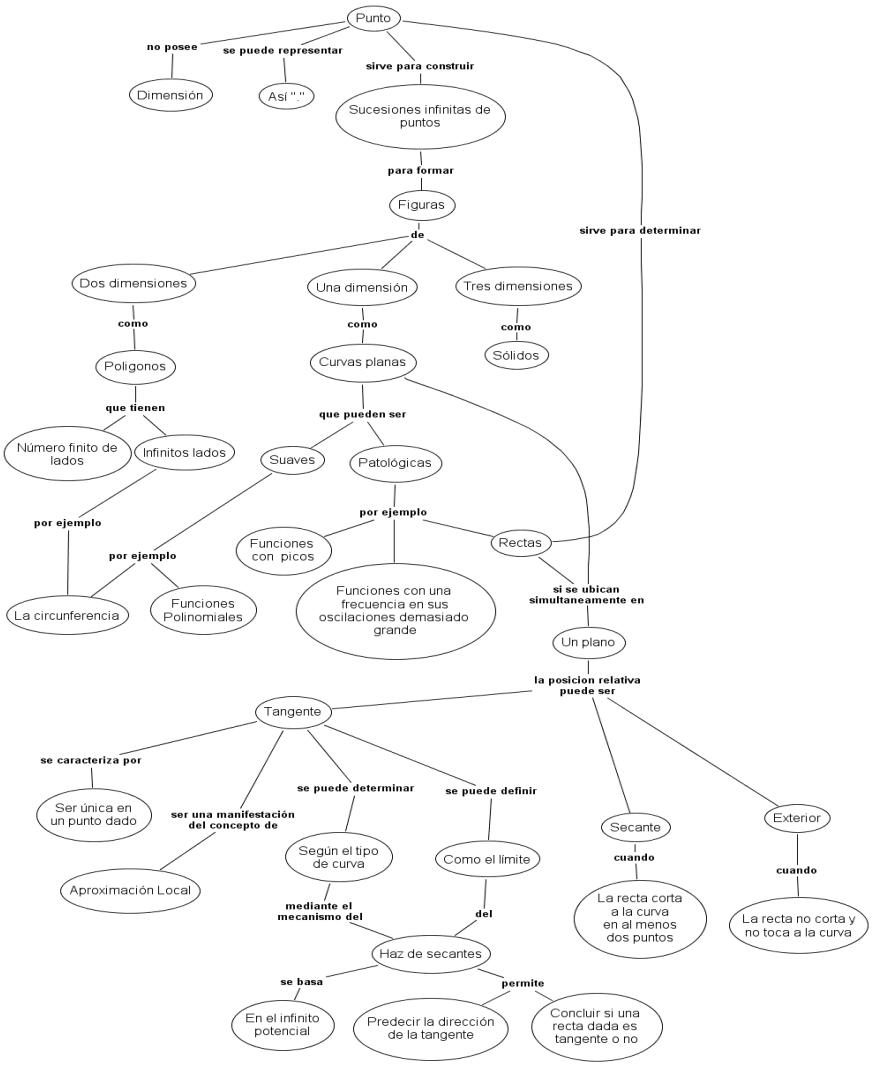


Figura 1. Mapa del experto, realizado por el grupo de investigación.

3.1 Fase de información

Debido a que esta fase de aprendizaje permite recopilar la información que poseen los alumnos en su estructura cognitiva acerca del objeto de estudio y los elementos que lo componen, se les pidió a los alumnos que realizaran un mapa conceptual con el fin de analizar las relaciones que realiza frente al concepto en su estructura cognitiva.

La Figura 2 muestra como el alumno relaciona algunos de los conceptos propuestos, por ejemplo el de punto, que es considerado objeto primitivo de la geometría. Además, define la recta tangente a una curva como "el tipo de recta que corta a la función en infinitos puntos, y corta a la circunferencia en un solo punto", mostrando que no comprende claro el concepto y sigue manteniendo la idea de la definición de tangente a una circunferencia. Lo anterior es una evidencia de que los alumnos no consideran la necesidad de definir la recta tangente a través de una propiedad adicional que esta tiene: la de ser la recta de estabilización del proceso del haz de secantes. El mapa realizado para la fase 1 de la experiencia es representativo, ya que la mayoría de los alumnos sometidos a ella presentaron otros similares.

Con el análisis de los mapas presentados, se puso de manifiesto que era necesario mejorar las relaciones significativas entre los conceptos propuestos, la forma como comprenden estos y establecer las relaciones relevantes que les faltan para completar los elementos básicos de la red de relaciones del nuevo nivel. Creando la necesidad de diseñar experiencias de aprendizaje en las que el mecanismo se aplique a diferentes situaciones físicas y geométricas

que conlleven a la apropiciación del concepto de infinito potencial, a la interiorización de la noción de aproximación y al establecimiento de su relación con el mecanismo seleccionado.

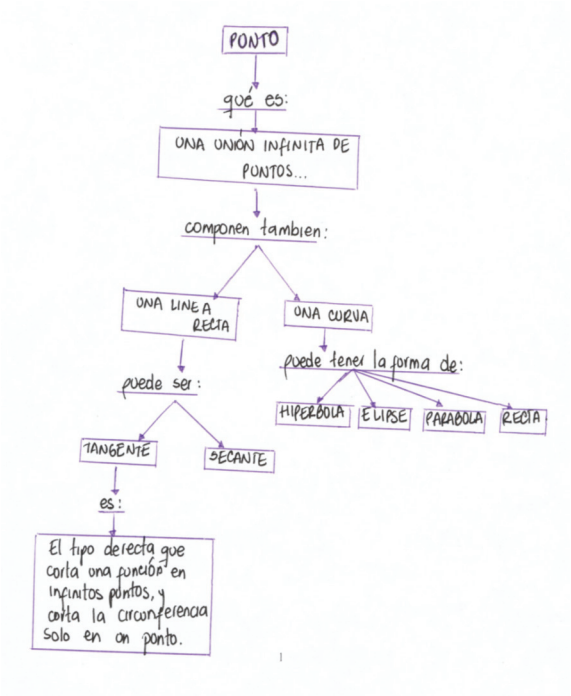


Figura 2. Mapa realizado para la fase de información.

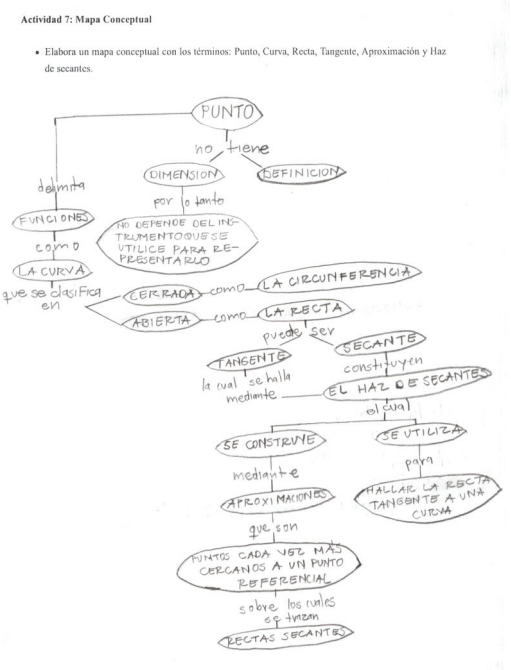


Figura 3. Mapa realizado para la fase de orientación dirigida.

3.2 Fase de orientación dirigida

A partir de esta información se diseñan las experiencias de aprendizaje para la fase 2. En ella cuando se les pide a los alumnos que realicen el mapa conceptual, y de su análisis se hace evidente (ver Figura 3) un progreso respecto a la fase anterior, pues los alumnos conservan los conceptos básicos, sus propiedades y adicionalmente relacionan el mecanismo del haz de secantes como una propiedad adicional para la definición del concepto de recta tangente, siendo esto último una condición necesaria para progresar del nivel II al nivel III de razonamiento del modelo educativo de van Hiele. Para esta etapa del proceso, se muestra un mejoramiento en la capacidad de razonamiento de los alumnos frente al concepto estudiado.

3.3 Fase de explicitación

En esta fase de aprendizaje los alumnos inician un proceso de separación de conceptos y establecen una jerarquía entre los términos utilizados al comienzo del mismo. Así mismo, los alumnos diferencian los procesos "mentales" de los procesos "físicos", entendiendo el manejo del mecanismo como un proceso dinámico, totalmente diferente a la concepción que presentaban al inicio de la experiencia, donde afirmaban que "este proceso puede terminar", ver la Figura 4. Es importante resaltar que si esta concepción no hubiese sido superada por alumnos la dualidad entre el concepto imagen y el concepto definición no les permitiría avanzar en su nivel de razonamiento tal como lo indican los descriptores separación del modelo para el concepto de tangente.

3.4 Fase de orientación libre

En esta fase los alumnos relacionaron el concepto estudiado con otros conceptos matemáticos o físicos como son el de velocidad y aceleración, y se les pidió que dibujaran curvas en las que no se pudiera utilizar el mecanismo del haz de secantes. Estas actividades fueron muy importantes pues a través de los mapas conceptuales se pude ver la evolución si se analizan los mapas de las Figuras 4 y 5.

3.5 Fase de integración

En esta fase se debe observar como el alumno ha reorganizado y reformulado su red conceptual entorno al concepto objeto de estudio. El mapa presentado en la Figura 5, resalta una de las características más importantes del aprendizaje significativo, que es una fuerte interacción entre los conocimientos más relevantes de la estructura cognitiva y el nuevo conocimiento adquirido. Esto se ve reflejado cuando el alumno construye relaciones entre el mecanismo del haz de secantes y los conceptos de límite y de derivada, que evidencia una ampliación considerable de su red de relaciones entorno al concepto de aproximación local.

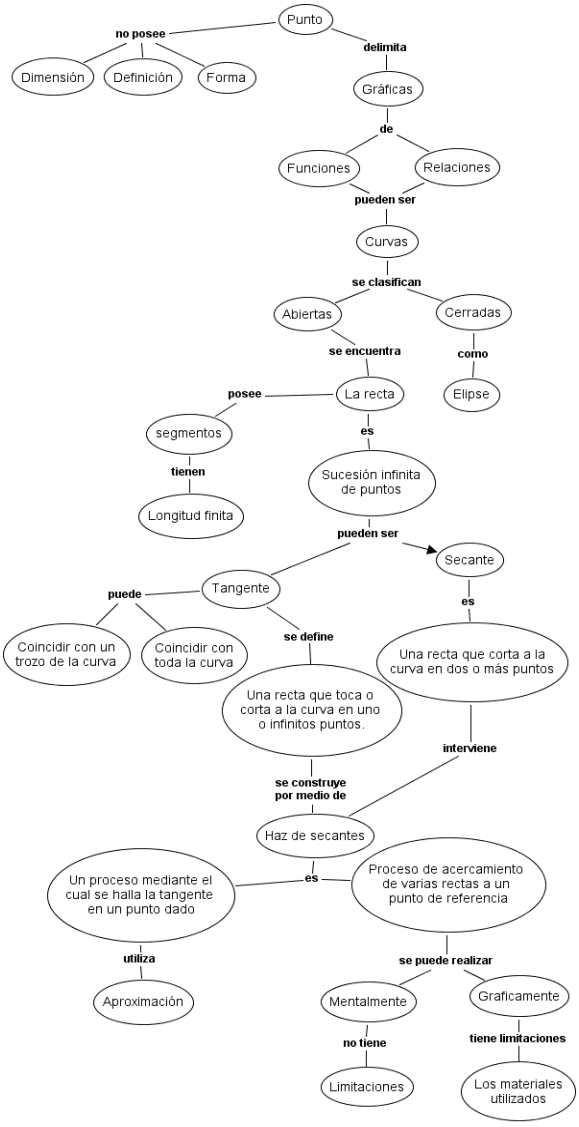


Figura 4. Mapa realizado para la fase de explicitación.

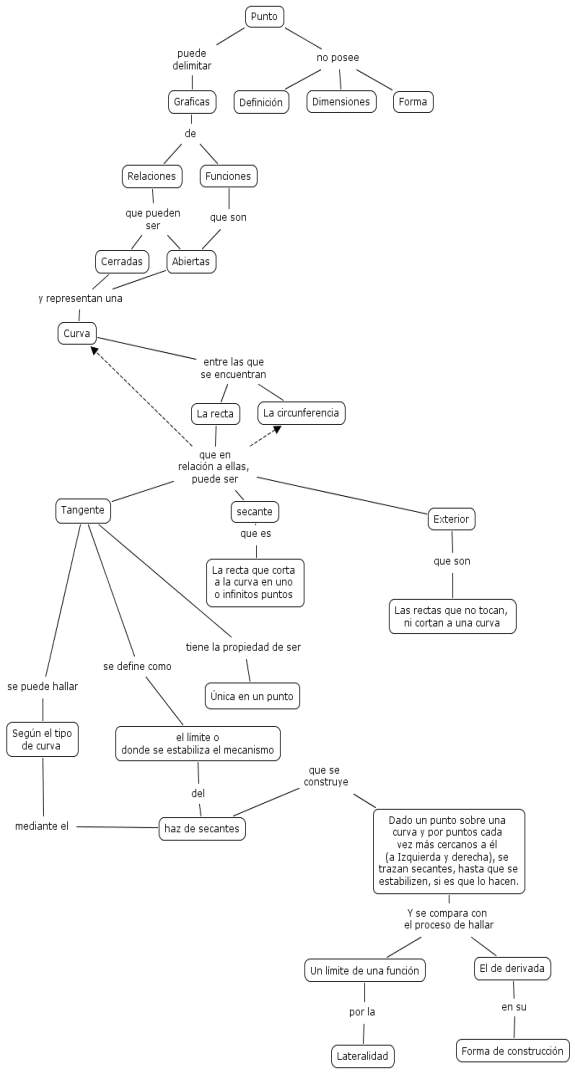


Figura 5. Mapa realizado para la fase de Integración.

Por la naturaleza de esta fase, el mapa de la Figura 5, muestra la evolución del lenguaje utilizado. Por ejemplo, cuando utilizan el concepto de curva y punto en varias partes del mapa (que no es lo ideal), cumple con el requisito de integrar varios conceptos que originalmente aparecían desligados dentro del mismo. La construcción de mapas conceptuales en cada una de las fases le ayudo a los alumnos a progresar en su razonamiento con respecto al concepto de recta tangente a una curva plana. Comprendieron que la tangente es un concepto dinámico y que para elaborar razonamientos a partir del mecanismo del haz de secantes deben hacerlo teniendo en cuenta el paso al límite que es su característica fundamental.

4 Conclusiones

La elaboración de mapas conceptuales enmarcados dentro del modelo educativo de van Hiele permite una nueva forma de exploración de las condiciones propias del modelo, especialmente en el análisis del lenguaje empleado por los alumnos durante la intervención pedagógica. Además, se puede hacer un mejor seguimiento y evaluación de la nueva red de relaciones, de la forma como ésta se va ampliando y mejorando durante el proceso propiciando el *insight* (la comprensión), objetivo fundamental del modelo de van Hiele. Así mismo, de los 39 alumnos participantes en el grupo experimental 38 progresaron del nivel 2 al nivel 3 de razonamiento. Además, todos los participantes mejoraron en la construcción de mapas conceptuales, en el uso del lenguaje y en la resolución de los tests propuestos en cada una de las experiencias de aprendizaje a las que fueron expuestos. Los resultados mostrados indican que el diseño de módulos de instrucción se puede continuar aplicando a otros conceptos del análisis matemático.

5 Reconocimientos

Este trabajo se enmarca en el proyecto de investigación "Una metodología alternativa para la enseñanza y el aprendizaje del concepto de límite", COLCIENCIAS 115-11-12704, y en el programa de Maestría en Educación con énfasis en docencia de las matemáticas, de la Universidad de Antioquia en convenio con la Universidad Eafit.

6 Referencias

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1989). Psicología educativa. Trillas, México.

Campillo, Pedro (1999). La noción de continuidad desde la óptica de los niveles de van Hiele. PhD thesis, Universidad Politécnica de Valencia, España.

de la Torre, A. F. (2000). La modelización del espacio y del tiempo: su estudio vía el modelo de van Hiele. PhD thesis, Universidad Politécnica de Valencia, España.

Esteban, P. V. (2000). Estudio comparativo del concepto de aproximación local vía del modelo de van Hiele. PhD thesis, Universidad Politécnica de Valencia, España.

Esteban, P. V., Bedoya, J. A., & Vasco, E. D. (2004). Los mapas conceptuales como herramienta de exploración del lenguaje en el modelo de van Hiele. Concept Maps: Theory, Methodology, Technology. Proc. of the First International Conference on Concept Mapping, 2 (1):151–154.

Fuys, David & Geddes, Dorothy & Tischler, Rosamond (1988). The van Hiele model of thinking in geometry among adolescents. Journal for Research in Mathematics Education, Monograph Number 3, Third printing 2002, USA.

Gutierrez J. (1990). Una propuesta de fundamentación para la enseñanza de la geometría: El modelo de van Hiele. Teoría y práctica en educación matemática, 1(4), 295–384.

Jaramillo, C. M. (2000). La noción de serie convergente desde la óptica de los niveles de van Hiele. PhD thesis, Universidad Politécnica de Valencia, España.

Llorrens, J. L. (1994). Aplicación del modelo de van Hiele al concepto de aproximación local. PhD thesis, Universidad Politécnica de Valencia, España.

Navarro, María (2002). Un estudio de la convergencia encuadrada en el modelo educativo de van Hiele y su correspondiente propuesta metodológica. PhD Thesis, Universidad de Sevilla, España.

Novak, J. D., & Gowin, D. B. (1999). Aprendiendo a Aprender. Martínez Roca, Barcelona.

Van Hiele, P. (1957). El problema de la comprensión: en conexión con la comprensión de los escolares en el aprendizaje de la geometría. PhD thesis.

Van Hiele, P. (1986). Structure and insight. A theory of mathematics education. Developmental Psychology Series, Academic Press Inc., Orlando.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

MAPAS CONCEPTUALES EN LAS AULAS PANAMEÑAS: APTITUD PARA CAMBIAR ACTITUD

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Resumen. El trabajo con mapas conceptuales (MC) en las aulas de clases puede lograr profundos cambios en la forma en que los estudiantes aprenden habilidades críticas para su desarrollo cognitivo y social. En Panamá la estrategia con los MC es clara: capacitar a docentes en el uso y aplicación de los MC en el aula de clases y ofrecerles apoyo mediante visitas regulares. Evidentemente, como en toda actividad humana, los resultados presentan diversos matices, algunos más favorables que otros. Dentro de dichos matices felizmente existen casos muy interesantes, por los resultados significativos que un docente haya alcanzado implementando los MC en su salón de clases. Este artículo apunta a destacar cómo la labor docente está directamente relacionada con alcanzar el éxito, si definimos el éxito como lograr cambios en la forma en que los estudiantes construyen su conocimiento.

1 Introducción

Las innovaciones en educación parecen ser un tema muy difundido y sobre el cual todos compartimos expectativas similares. En la actualidad contamos con un variado conjunto de herramientas encaminadas a desarrollar habilidades en los estudiantes. Sin embargo, en muchos casos, estas herramientas no consiguen ser lo suficientemente efectivas. Cada vez se hace más palpable que con seguridad, la única habilidad clave en el futuro inmediato es la de aprender significativa y constantemente. Esto implica que en ese proceso, el desaprender y reaprender sean el foco de atención permanente en las instituciones llamadas a preparar estas habilidades, es decir, en las escuelas.

En Panamá el panorama se vislumbra favorable, con la implementación de proyectos que persiguen el desarrollo de esas habilidades críticas para sus ciudadanos. Una iniciativa del Gobierno de Panamá es el *Proyecto Conéctate al Conocimiento* (Tarté, 2006). Este proyecto pretende lograr cambios significativos en el sistema educativo panameño con la ayuda de herramientas como los mapas conceptuales (MC), promoviendo la integración curricular y con un enfoque hacia la construcción de conocimiento, todo esto con la tecnología como un medio que facilita lograr lo anterior. Inevitablemente este tipo de proyectos están atados a quienes son uno de los actores principales del proceso: los docentes. El maestro es el eslabón que permite hacer llegar cualquier innovación a los estudiantes. Es la figura capaz de amparar o rechazar cualquier estrategia educativa. La capacitación a los docentes es sólo la primera etapa que se desarrolla en el Proyecto. Una vez que los docentes han sido capacitados, se les brindan visitas periódicas, que tienen como propósito apoyar a los maestros en su trabajo. Es precisamente en estas visitas a las escuelas, cuando se puede palpar si los esfuerzos se están traduciendo en mejores formas de aprender para los estudiantes, por eso es que se afirma que el maestro es capaz de transformar la manera en que sus estudiantes aprenden.

2 No Existe una Receta, Sólo cambio de Enfoque y Cambio de Actitud

Es precisamente en las aulas de clases en donde cobran un sentido extraordinario las herramientas, pues son capaces de transformar la manera en que los estudiantes pueden aprender. Todo esto es consecuente con la idea de utilizar dichas herramientas como lo que son: "herramientas". El enfoque debe estar siempre en los procesos que se desarrollan con estas herramientas. Los MC son herramientas que permiten representar gráficamente el conocimiento, y éste último está basado fundamentalmente en conceptos y proposiciones (Novak, 1984). Por esta razón los MC son una de las más poderosas herramientas para "retratar" lo que un estudiante conoce sobre un tema; pero más aún, permiten ver el proceso de aprendizaje y cómo el estudiante logra sumergirse en lo más profundo del conocimiento.

Los MC no deben ser un fin en sí; el *proceso de construcción* de los MC y la indagación constante del docente y del estudiante es lo admirable de esta herramienta. Quien construye un MC, está forzosamente sometido a un profundo análisis y reflexión, que no le da mayores alternativas que construir conocimiento y aprender. Por esta razón es claro que los MC son un medio ideal para transformar mentes.

El trabajo con MC ni siquiera insinúa que, con sólo usarlos, el estudiante tendrá un conocimiento extenso del tema. Por el contrario, lo ideal de los MC es que ponen de manifiesto lo que se conoce, y evidencian lo que queda por aprender.

A pesar de lo que sabemos acerca de los MC, podría decirse que hacer que los estudiantes alcancen aprendizajes significativos con su uso es una tarea casi exclusiva del maestro en el aula. En el caso más extremo, el maestro da el MC a sus estudiantes para que lo copien y memoricen, para luego poner un examen en el cual tienen que rellenar espacios vacíos. En ese caso la construcción de conocimiento y el aprendizaje son casi nulos. Puede surgir una interrogante: ¿Existe una manera efectiva de lograr mejores aprendizajes con el uso de los MC en las aulas de clases? Categóricamente todos pensaríamos que existen estrategias que pueden definirse como más efectivas que otras, pero para nada se está suponiendo que son infalibles.

La experiencia de los maestros en las escuelas de Panamá refleja lo contextualizado que puede ser el trabajo con MC. Al ser capacitados durante dos semanas en el taller del *Proyecto Conéctate al Conocimiento*, los maestros de diversas regiones educativas de Panamá regresan a sus labores docentes llevando consigo una maleta llena de enfoques educativos innovadores y herramientas fabulosas. Sin embargo, cuando vuelven a sus aulas es cuando se puede apreciar cuánto logran desempacar de dicha maleta. La mayoría se siente diferente y empieza a trabajar con los MC con un cierto temor, con muchas preguntas: *¿Cómo los introduzco? ¿No serán muy difíciles para los niños? ¿Y si no les gustan?* En esencia, y a pesar de lo anterior, se aventuran a utilizar la herramienta. La pregunta clave para nosotros es ¿cómo se podría afirmar que la estrategia ha tenido algún éxito? Para quienes sean muy positivos, el simple hecho de que los maestros usen los MC con un enfoque constructivista ya representa un cambio radical, pero se precisa tener una medida más concreta para saber si los maestros están cambiando la manera en que sus estudiantes construyen conocimiento.

En esa perspectiva es que se dan las visitas de apoyo a los maestros. Estas visitas permiten observar cómo se está desarrollando el uso de los MC en clases y dar una retroalimentación. Los maestros expresan las dificultades que han tenido y también los logros que sus estudiantes han obtenido. Lo destacable de la labor docente son los logros de los estudiantes al presentar cambios en aspectos cognoscitivos y sociales; los MC son sólo un vehículo para alcanzar esos cambios. Los estudiantes gradualmente han de pasar a ser mucho más investigativos, desarrollar la colaboración a niveles sin comparación, mejorar su capacidad de expresión oral y escrita y cuantitativamente mejorar sus calificaciones. Al percibir dichos cambios no queda otra alternativa que preguntarse ¿qué puede marcar la diferencia en los estudiantes?

La primera pregunta que surge es ¿Cómo logramos estos cambios? En realidad este artículo no aspira ha ser la respuesta definitiva a esa interrogante, sin embargo, intentamos resaltar de manera general aspectos relevantes de la labor docente. Sabemos que las condiciones en las que se encuentran los estudiantes siempre serán únicas e irrepetibles. Nos disponemos a describir la estrategia que se utilizó en el uso de los MC con estudiantes de 6º básico de la escuela Evelio D. Carrizo ubicada en la provincia de Herrera, República de Panamá. A manera puntual señalamos que esos aspectos básicamente se separan en dos momentos de la implementación: Introducción de MC y Usos de MC como medio para aprender significativamente.

2.1 Introducción de MC

- Se inició la construcción de los MC con temas cotidianos y de interés para los niños. Esto brindó ventajas obvias, pues facilitó que los estudiantes dominaran el contenido del MC y pudieran concentrarse en la elaboración. Se decidió hacer una lluvia de ideas para elegir los temas para estos primeros MC, y también una lluvia de ideas para establecer los conceptos relevantes del tema una vez escogido. Se les formulaba una pregunta de enfoque, asegurándose de que fuese una pregunta que estimulara el análisis y la discusión.
- Realizaron los primeros MC en forma colectiva, en el pizarrón, con la participación activa de todos los estudiantes. Esto les dio confianza a los estudiantes para experimentar el proceso de construcción. Es importante en todo momento que el docente asuma un rol de guía en la discusión y que destaque la forma en que el MC va cambiando por las preguntas que suelen surgir, rumbo siempre a una inevitable mejora, señalando abiertamente que no hay MC malos, todo MC puede ser mejorado.
- Después de dos sesiones en las que hicieron MC en la pizarra, empezaron a construir MC en láminas de papel. Los hacían en equipos numerosos. Esto fue clave en el desarrollo de la colaboración entre los

estudiantes. En los equipos claramente se distinguió a aquellos estudiantes que estaban teniendo rápidos avances con los MC. Una vez que se logró identificar a dichos estudiantes, se dispuso, en posteriores sesiones, redistribuir los equipos procurando que esos niños fuesen "orientadores" de sus otros compañeros.

- Todos estos aspectos son previos a la utilización de los MC como herramientas para desarrollar contenidos curriculares. Quedó en evidencia que es necesario invertir tiempo para que los estudiantes se sientan cómodos con los MC antes de introducir contenidos curriculares. El aspecto emotivo es fundamental en el proceso de aprender con MC, pues si el maestro y/o el estudiante no se sienten a gusto con la herramienta, la van a desechar con prontitud. El proceso no se trata sólo de hacer MC, sino de aprender haciendo MC. Por tal motivo, no se puso mucho énfasis en cómo quedaban los MC al final de las sesiones. Más atención merecía que los niños participaran y que expresaran sus ideas, haciendo hincapié en las razones por las que un estudiante elaboraba una proposición y no en la forma de ésta.
- Cabe señalar que este proceso tomó un número plural de sesiones, hasta que se notó que las limitaciones de uso de la herramienta habían sido superadas. De ese momento en adelante, empezaron a usar los MC para que los niños aprendieran los contenidos curriculares.
- En la escuela se cuenta con un aula con computadoras, las cuales tienen el programa CmapTools 3.9 (Cañas et al., 2004). Esta aula es utilizada por todos los niños de la escuela. La herramienta tecnológica en todo momento fue un apoyo para que los niños construyeran sus MC, investigaran en Internet y colaboraran. El uso de las computadoras fue un proceso absolutamente transparente y no hizo falta explicar cada parte de las máquinas y cada opción de los programas, es decir, se prescindió de una alfabetización computacional.

2.2 Usos de los MC como Medio para Aprender Significativamente

- La construcción empezó en equipos numerosos. Luego se redujo la cantidad de integrantes por equipo, se rotaron los equipos en cada actividad, procurando que en cada equipos hubiera un "orientador", que no era más que un niño que se empezaba a destacar y que tenía que ayudar a su equipo a construir los MC. Poco a poco el número de "orientadores" era mayor, así que se determinó que trabajaran en parejas, las cuales también eran rotativas. Así se mantuvieron por algún tiempo, hasta que empezaron a trabajar individualmente. Pero esta última estrategia sólo permitía saber si cada niño poseía una determinada destreza en la construcción. La mejor forma era cuando trabajaban en equipos de cuatro o cinco estudiantes, pues se apreciaba cómo discernían, colaboraban y reflexionaban para construir los MC.
- Se deseaba elaborar MC en una sola asignatura, pues esto podría ser útil si se deseaba observar avances y establecer comparaciones, pues este grupo era el mismo que había cursado el 5º el año anterior. La intención era determinar si se apreciaría alguna mejoría en las calificaciones en esa asignatura, en comparación con las demás asignaturas en las que no iban a usar MC. Para esto hubo una negociación con los estudiantes para saber en qué asignatura deseaban ellos usar los MC, esto claro, luego de que ellos ya manejaban la herramienta. Los niños acordaron utilizarlos en Ciencias Naturales.
- Los MC duraban varios periodos de clases. Por ejemplo, un tema como la atmósfera iniciaba con una clase, luego de ésta, los niños individualmente hacían un MC. Después discutían en plenaria algunos MC hechos por los niños, luego se reunían en grupos y consensuaban un MC por equipo y entonces realizaban trabajos de investigación y empezaban a ampliar los MC. Todo esto ocurría en varias sesiones, donde se continuaba profundizando en el tema de la atmósfera y los nuevos conceptos dados se incorporaban a los MC. En la figura 1 se aprecia un MC acerca de la atmósfera. . Después de algunas clases, discusiones e investigaciones, el niño irremediablemente modificaba ese MC.
- Los niños se sentían satisfechos y orgullosos de sus trabajos. Al conversar con ellos se percibía que definitivamente dominaban el contenido de los MC, porque ellos los habían construido. Se encontraban en perfecta conjunción el conocimiento y la alegría de tenerlo. Una manera de mantener el interés por parte de los niños era hacer ver que aprender es lo que importa y no la calificación al final del trabajo; es el trabajo el que merece ser valorado. Por esto se celebraba el éxito alcanzado por todos, sin importar que existieran MC "mejor" elaborados que otros. Todos los equipos construían conocimiento y eso es algo que no acaba jamás y por lo que es bueno celebrar. Eso también permitió que los niños se comprendieran entre sí y sobre todo que se apoyaran; la marcada colaboración al construir los MC hizo desarrollar habilidades sociales en los estudiantes.

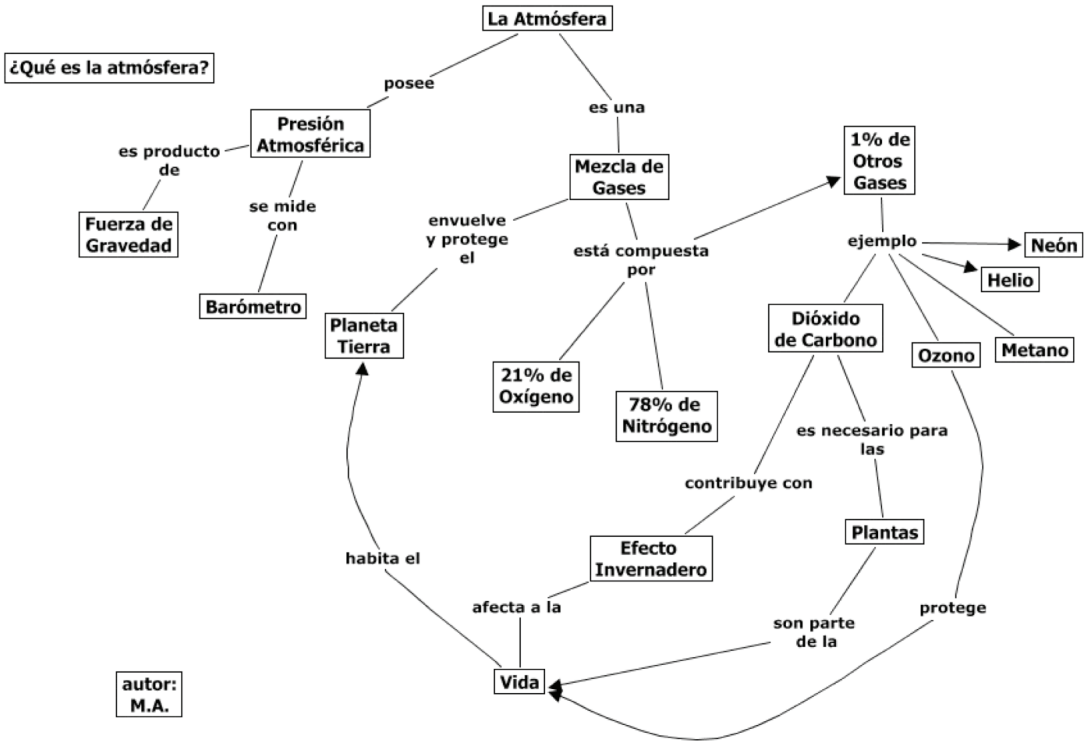


Figura 1. MC acerca de la atmósfera elaborado por un estudiante de 6º, Escuela Evelio D. Carrizo, Herera, Panamá.

Obviamente, todo este registro anecdótico no representa la estrategia a seguir por todos, pero muestra claramente algunas maneras que han resultado efectivas para trabajar con los MC. Sabemos que no podemos generalizar, debido a las condiciones especiales de cada persona, lugar y tiempo, pero sí podemos intuir que el trabajo con MC requiere una dedicación especial que sólo el maestro es capaz de tener. El maestro debe ser un profesional involucrado con la investigación, pues tiene ante él un pequeño "laboratorio" que le permite descubrir maneras diferentes de hacer su labor, es decir, innovar en educación. Así, el maestro debe ser el primer actor innovador en la escuela.

3 ¡Aprendizajes Exitosos…Y ¿Cómo lo Sabemos?

¿Qué prueba que un estudiante haya aprendido significativamente algún tema? ¿Acaso un examen tradicional con su respectiva calificación pone de manifiesto las habilidades que suponemos se deben haber desarrollado? Podríamos pensar que no. Entonces, ¿Cómo lo sabemos? Es como si deseáramos obtener una radiografía de la mente y el pensamiento del estudiante, lo más cercano a eso es, precisamente, pedirle que haga un MC. En el MC pondría de manifiesto si comprendió cabalmente el tema. Pero ¿Qué sucede con otras habilidades importantes como la colaboración? Definitivamente se requiere de una percepción muy fina para notar cambios en las estructuras de pensamiento de los estudiantes. Conlleva observar cuidadosamente. En el caso de los estudiantes de 6° de la Escuela Evelio D. Carrizo, ¿Cómo sabemos que lo que se hizo tuvo resultados favorables? Podrían tomarse diversos indicadores, tanto cualitativos como cuantitativos, pero deberíamos esperar investigar con mayor profundidad, para ver si estos resultados pudieran deberse a diversas aristas, y no necesariamente al uso de MC.

4 Resultados/ Evaluando Procesos

4.1 Indicadores Cualitativos

Disponemos de la experiencia en el aula de clases para visualizar cambios en el trabajo de los alumnos. El MC de la figura 2 muestra algunos aspectos relevantes que se observaron en el trabajo con el grupo de estudiantes.

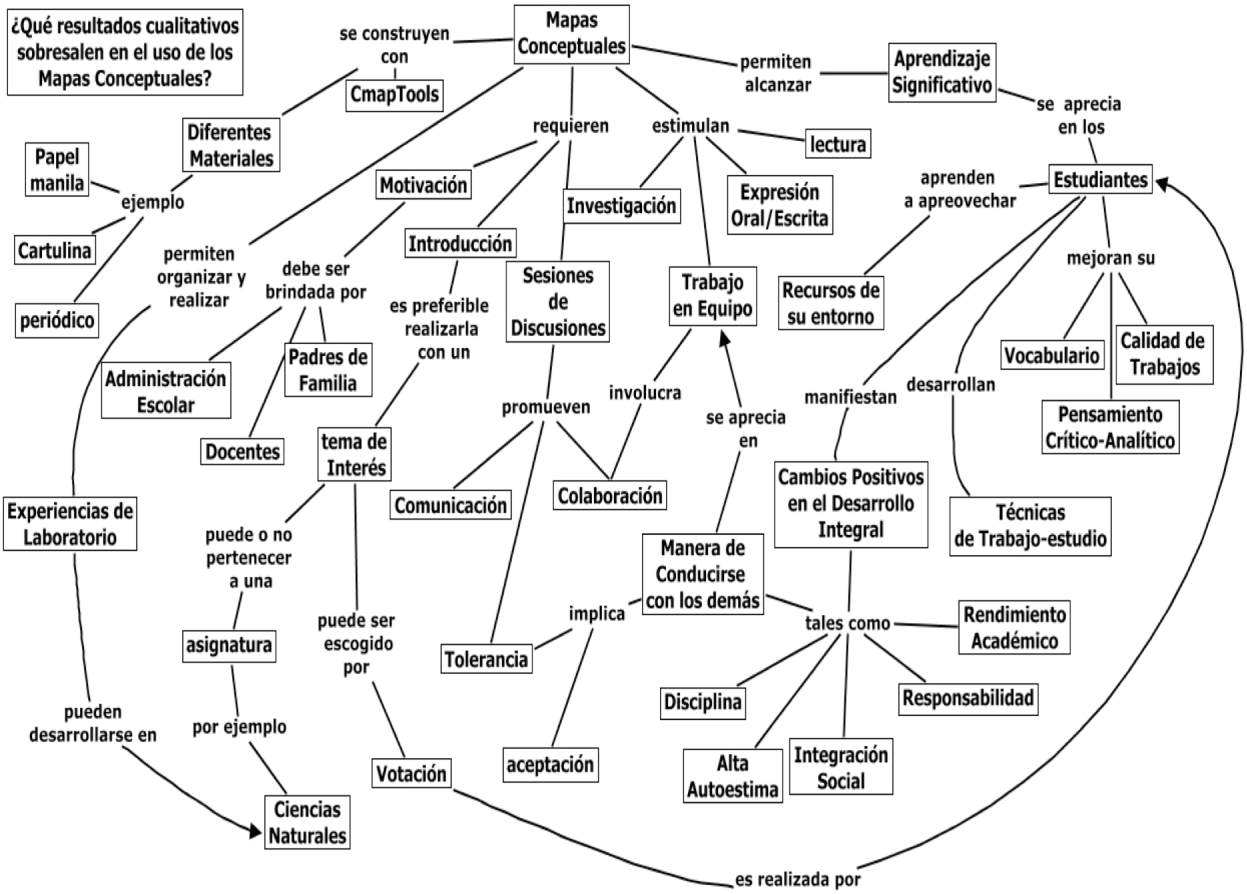


Figura 2. MC que destaca los aspectos cualitativos que se lograron apreciar en el grupo de estudiantes de 6º de la Escuela Evelio D. Carrizo.

Otras experiencias que podemos citar:

- En una ocasión a la escuela llegó un grupo de estudiantes universitarios de la Facultad de Educación, quienes deseaban conocer la estrategia metodológica que se ejecutaba en la escuela. Los niños fueron quienes presentaron sus trabajos y explicaron con mucha claridad todo lo que habían alcanzado con el uso de los MC y los proyectos colaborativos. Esa fue una experiencia enriquecedora para todos.
- Se les podía ver con un entusiasmo y una prontitud a la hora de hacer los MC. La construcción de MC en la computadora (CmapTools) fue una motivación adicional de importante impacto para ellos. Cuando se les mencionó que tendrían computadoras para hacer MC y acceso a Internet, se maravillaron. Cuando las computadoras llegaron a la escuela ellos aprendieron a utilizarlas rápidamente. Al inicio pasaban sus MC del papel al programa, porque no tenían más que una hora a la semana para usar las computadoras, pero luego empezaron a usar las computadoras para investigar, consultar, intercambiar, enriquecer y mejorar los MC. Las computadoras por sí mismas no producen aprendizajes, el uso adecuado de ellas sí lo produce. Tanto fue el entusiasmo de algunos estudiantes, que decidieron instalar el CmapTools en computadoras de sus casas o en los Café Internet cercanos y lo que causa admiración es que a pesar de que ellos ya no asisten a la escuela (porque terminaron su básica y se fueron a diversos colegios) continúan haciendo MC y siguen llamándose para comparar lo que están haciendo. Los profesores de sus colegios no trabajan con

MC, pero los niños por su cuenta estudian las clases usando MC para saber si entendieron los temas. Esto pone en evidencia que los niños se han apropiado de las herramientas y que reconocen su valor, pues no lo hacen por cumplir, o por una nota, sino que lo hacen para lograr aprender.

4.2 Indicadores Cuantitativos

Para determinar diferencias significativas en los promedios de los estudiantes, se hace necesario un control de variables muy grande, sobre todo si se desea atribuir estas diferencias a causas conocidas. Como se mencionó, al usar MC con los estudiantes de 6º de la Escuela Evelio D. Carrizo, se pensó utilizarlos en una sola asignatura, en Ciencias Naturales, esto permite realizar comparaciones. La muestra para este estudio fue de 18 estudiantes (75% del total de estudiantes del grupo, pues no fue posible obtener el resto de los registros).

Se calculó el promedio de los promedios finales, es decir un promedio final del grupo para 2004 y un promedio final del grupo para 2005 en cada asignatura, y sus respectivas desviaciones estándar (δ). La Tabla 1 muestra estos valores y además el valor de la probabilidad (P). Este valor se calcula para determinar si una variación en un promedio se debe a alguna causa (significativa) o es producto de factores aleatorios. El valor P está calculado para un nivel de confiabilidad de un 95%, esto es si $P < 0,05$ entonces la variación es significativa, de lo contrario se considera como una variación no significativa.

En las gráficas de la figura 3 se aprecian las distribuciones de los promedios finales de los estudiantes en los años 2004 y 2005 para las asignaturas[1] de Ciencias Naturales (figura 3a), Español (figura 3b), Matemáticas (figura 3c) y Ciencias Sociales (figura 3d). Al comparar estos dos promedios, se constata una diferencia significativa entre el promedio del grupo en Ciencias Naturales en 2004 y el promedio del grupo en Ciencias Naturales en 2005.

Asignatura/Año	Promedio Final del Grupo	δ	Valor P (Diferencia Significativa)
Ciencias Naturales/04	4,21	0,74	
Ciencias Naturales/05	4,72	0,25	0,0112 (significativa)
Ciencias Sociales/04	4,24	0,54	
Ciencias Sociales/05	4,38	0,43	0,3987 (no significativa)
Español/04	4,22	0,47	
Español/05	4,21	0,49	0,9505 (no significativa)
Matemáticas/04	4,28	0,56	
Matemáticas/05	4,34	0,45	0,7274 (no significativa)

Tabla 1. Comparación entre Promedios Finales de Grupo para 2004 y 2005 para la asignatura de Ciencias Naturales. Fuente: Registros Académicos Escuela Evelio D. Carrizo, Herrera, Panamá

5 Discusión

La diferencia significativa en los promedios en Ciencias Naturales, única asignatura en la que se usaba MC, permite hacer diversos tipos de cuestionamientos. A pesar de que estos resultados sugieren un cambio, debemos preguntarnos que factores eran diferentes entre las asignaturas, claramente sabemos que unote ellos fue el uso de MC, sin embargo, no podemos asegurar que se deba sólo al uso de MC. Existen múltiples factores que probablemente influyan en éste resultado. Por ejemplo, el cambio de metodología y la manera de realizar las evaluaciones cambió en Ciencias Naturales y no en las otras asignaturas, las cuales siguieron siendo llevadas habitualmente. Algo destacable es que en Ciencias Naturales las pruebas pasaron a ser basadas en preguntas abiertas acerca de los temas, como por ejemplo: ¿Qué aprendió sobre…? ¿Cuál es su opinión acerca de…? ¿Cuál es la importancia de…? Esta manera de evaluar pudo influir en aspectos cuantitativos; sin embargo, los aspectos cualitativos citados fueron muy apreciables. La motivación por usar las computadoras puede ser otro factor, el hecho es que hubo cambios, que responden al perfil que se busca con todas las innovaciones que se incorporaron.

[1] Normalmente los estudiantes cursan un número de 9 asignaturas, sin embargo sólo 4 asignaturas básicas (Ciencias Naturales, Español, Matemáticas y Ciencias Sociales) son impartidas por el mismo maestro, el resto son las llamadas "asignaturas especiales" (Inglés, Religión Moral y Valores, Expresiones Artísticas, Educación Física, Tecnologías) las cuales son dadas por docentes diferentes. Este artículo está basado en el trabajo con las asignaturas básicas que eran impartidas por el mismo docente para evitar implicar otro tipo de factor al ser diferentes docentes en las otras asignaturas.

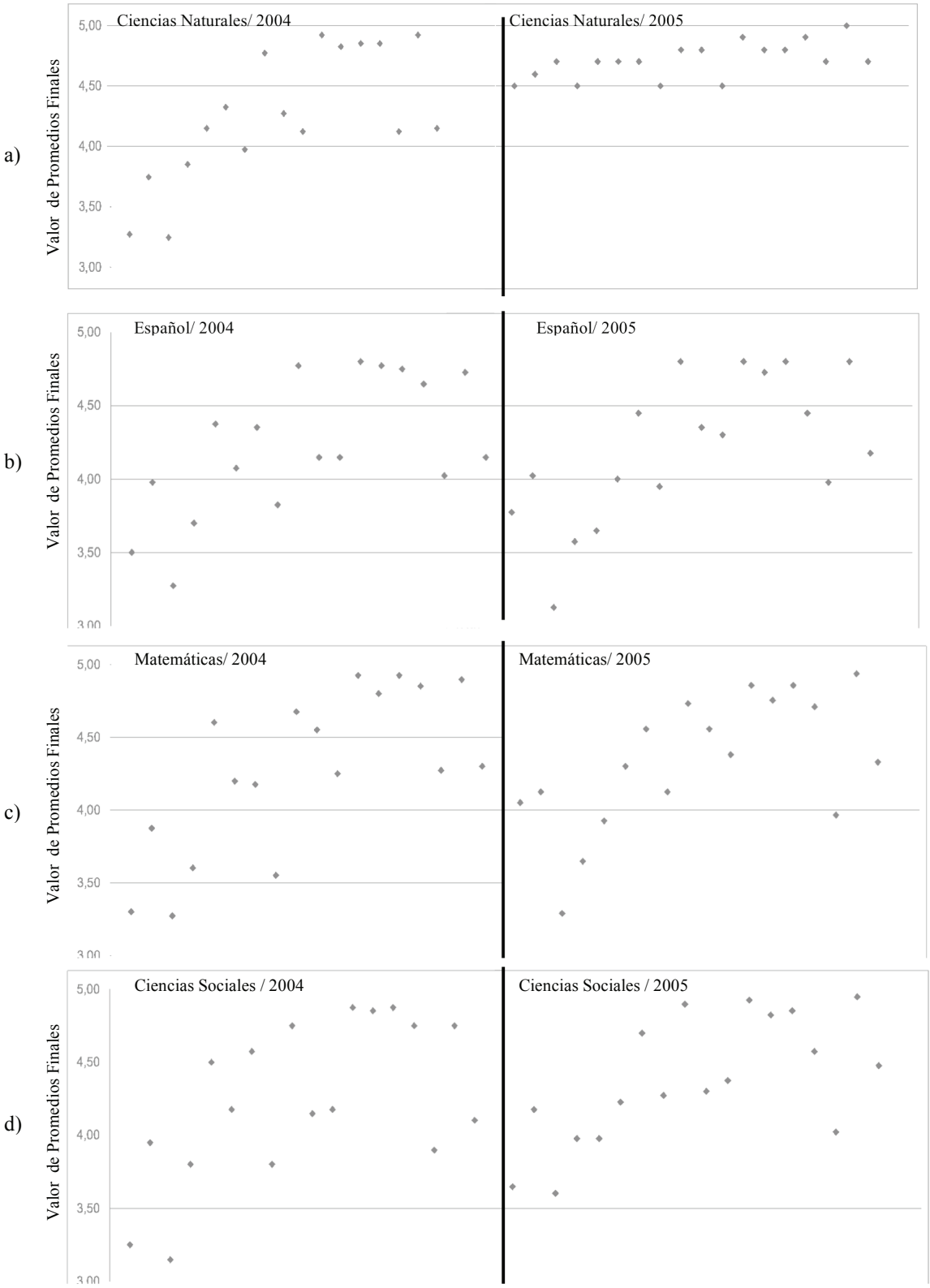


Figura 3. Comparación entre las Distribuciones de Promedios Finales para los Años 2004 y 2005 en: a) Ciencias Naturales, b) Español, c) Matemáticas, d) Ciencias Sociales. Fuente: Registros Académicos Escuela Evelio D. Carrizo, Chitré, Panamá

6 Conclusión

Es necesario realizar una investigación mucho más controlada para determinar qué factor, incluyendo uso de MC, tiene una influencia más significativa en los cambios apreciados. Qué particularidades son del grupo y qué procesos son reproducibles. Lo cierto es que, dentro de todo lo diferente que se haya podido realizar en Ciencias Naturales, los MC eran una de las innovaciones, la cual no estaba presente en las demás asignaturas. El punto a interpretar es cuál es impacto que está teniendo el *Proyecto Conéctate al Conocimiento*, impacto traducido en nuevos enfoques basados en el aprendizaje, uso de MC y CmapTools, con todo lo que estas formas de trabajar ofrecen: espacios y tiempos para intercambio, investigación, exploración, análisis, discusión, colaboración y deseos de aprender. Por eso que al inicio de este artículo se señaló que "En Panamá el panorama se vislumbra favorable…". Hay que reconocer que es un ideal creer que estas experiencias se repetirán en todas las aulas del país, empleando el término "ideal" como la imagen remota de algo que se desea alcanzar, pero que sirve para avanzar lento pero constante hacia él; así es que el ideal requiere esfuerzo y dedicación, porque las herramientas y los métodos están, hace falta la cuota de motivación y empeño para que se logre ese ideal en un número alto de casos.

7 Agradecimientos

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8 Referencias

Cañas, A. J., Ford, K. M., Coffey, J., Reichherzer, T., Carff, R., Shamma, D., & Breedy, M. (2000). Herramientas para Construir y Compartir Modelos de Conocimiento basados en MC. *Revista de Informática Educativa, 13*(2), 145-158.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations.* Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

Tarte, G. (2006). Conéctate al Conocimiento: Una Estrategia Nacional de Panamá basada en Mapas Conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

MAPAS CONCEPTUALES HIPERMEDIALES PARA EVALUAR LA COMPRENSIÓN DE LECTURAS EN LENGUA EXTRANJERA

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Resumen. Los Mapas Conceptuales Hipermediales (MCH) constituyen una extensión de los Mapas Conceptuales (MC) de Novak con incorporación de tecnología computacional. Cabe destacar que esta propuesta se aleja de otras que implementan los MC en computadoras: para manejar su estructura hipermedial es necesario distribuir los conceptos en vistas; esta partición del conjunto de conceptos respeta la relación jerárquica existente entre ellos y no constituye una debilidad en el modelo sino que, por el contrario, exige al autor un nivel mayor de elaboración y abstracción en el proceso de construcción del conocimiento. En el marco de un proyecto universitario de investigación se diseñó e implementó un ambiente computacional con capacidades para construir MCH. A partir de esa plataforma y para poder medir resultados, se programó, entre otras, una experiencia interdisciplinaria que incluyó el uso de MCH en el desarrollo curricular de un curso universitario de Lectura Comprensiva de Textos en Inglés de nivel intermedio. Como parte de los resultados obtenidos de esta experiencia se presenta una nueva metodología de construcción que fortalece el uso de MCH como técnica de estudio. Además, a partir de la evaluación presencial surgió la necesidad de encarar un trabajo de reingeniería de la plataforma MCH con el propósito de rediseñar algunas de las operaciones.

1 Introducción

Los Mapas Conceptuales Hipermediales (MCH), basados en los Mapas Conceptuales (MC) presentados por Novak (Novak-Gowin, 1984), constituyen una valiosa herramienta que favorece los procesos de aprendizaje significativo. En particular los MCH con su componente hipermedial, exigen un nivel mayor en la elaboración del texto: la selección y jerarquización de conceptos en las vistas que conforman un MCH (Señas y otros, 2000) El uso de los MCH es válido en la enseñanza de cualquier disciplina y, en este caso, lo hemos podido comprobar en particular en la asignatura Curso de Lectura Comprensiva de Textos en Idioma Inglés – Nivel II. Esta es una materia universitaria que tiene por objetivo que los alumnos logren la compresión de un texto escrito en inglés, aún cuando no tengan un dominio fluido de la lengua. De esta manera, los MCH son una herramienta más de aprendizaje y se pueden insertar naturalmente en el proceso de enseñanza a lo largo del desarrollo curricular, incluso el proceso de evaluación.

La elaboración de un MCH sobre un tema no es una tarea trivial y requiere de una clara comprensión del mismo. Las experiencias en el aula con MCH muestran que los alumnos en general no tienen problemas con el aprendizaje de la técnica sino en la creación de mapas semánticamente correctos (Malet-Señas, 1999; Zanconi y otros, 1998). Las dificultades en la construcción del mapa dan nota de que aún no se ha logrado una comprensión del tema bajo estudio. Si para un texto dado, no se pueden determinar los conceptos fundamentales, jerarquizarlos y plantear las proposiciones que los vinculen, básicamente significa que no se ha comprendido el tema, esto es, no se ha logrado un aprendizaje significativo (Ausubel-Novak, 1978). Todas estas decisiones que un alumno tiene que tomar para construir un MCH lo llevan a analizar el texto más profundamente. En este sentido, el aporte de la metodología de construcción basada en las habilidades desarrolladas en el curso, es sumamente útil para los alumnos y permite la construcción de un MCH de mejor calidad. La experiencia también posibilitó redescubrir la construcción de MCH como técnica de evaluación. En el caso particular de la asignatura testigo, las producciones con MCH alejan las soluciones que tienden a la traducción literal, que se distancian del objetivo que persigue la asignatura.

2 Mapas Conceptuales Hipermediales

Los MCH son una extensión de los MC definidos por Novak (Novak-Gowin, 1984) y están enriquecidos por el aporte de tecnología hipermedial. Los elementos básicos que componen los MCH son: las vistas, los conceptos y las relaciones vinculares. Cada vista está asociada a una pantalla y plasma un número reducido de conceptos (tantos como se puedan captar a un "golpe de vista", según las teorías de la percepción, y proposiciones de un nivel jerárquico similar. Un concepto es "una regularidad en los acontecimientos o en los objetos que se designa mediante algún término" (Ontoria, 1992). Con dos conceptos relacionados se forma una proposición, esto es una unidad con significado semántico que tiene asociado un valor de verdad (Novak, 1984).

Los constructores básicos de los MCH se han heredado de aquellos propios de los MC. Sin embargo, fue necesario incorporar otros nuevos para mantener la estructura hipermedial. El MCH de un tema amplio va a estar formado por varias vistas. La navegación entre las vistas se realiza a través de dos mecanismos básicos: la búsqueda de la profundización de un concepto o de su relación con otros conceptos. El medio para ofrecer la navegación entre vistas lo proveen dos tipos de conceptos particulares del MCH: los no-terminales y los externos. Durante la actividad de inspección de un mapa, este tipo de conceptos actúan como "botones", posibilitando viajar desde una vista hacia otra. En la Figura 1 se presentan cuatro de las vistas de un MCH sobre un texto de Ciencias Naturales.

2.1 La plataforma para la construcción de MCH

Para la construcción de los MCH se diseñó e implementó la *Plataforma MCH* a partir de un modelo de especificación con los requerimientos funcionales de una herramienta adecuada para la creación y navegación de MCH. Se tuvo especial consideración en diseñar un producto que proporcione un ambiente de trabajo natural e intuitivo, considerando que entre los usuarios finales a quienes está dirigida esta herramienta se incluye tanto a docentes como a alumnos de cualquier disciplina (Zanconi y otros, 1998).

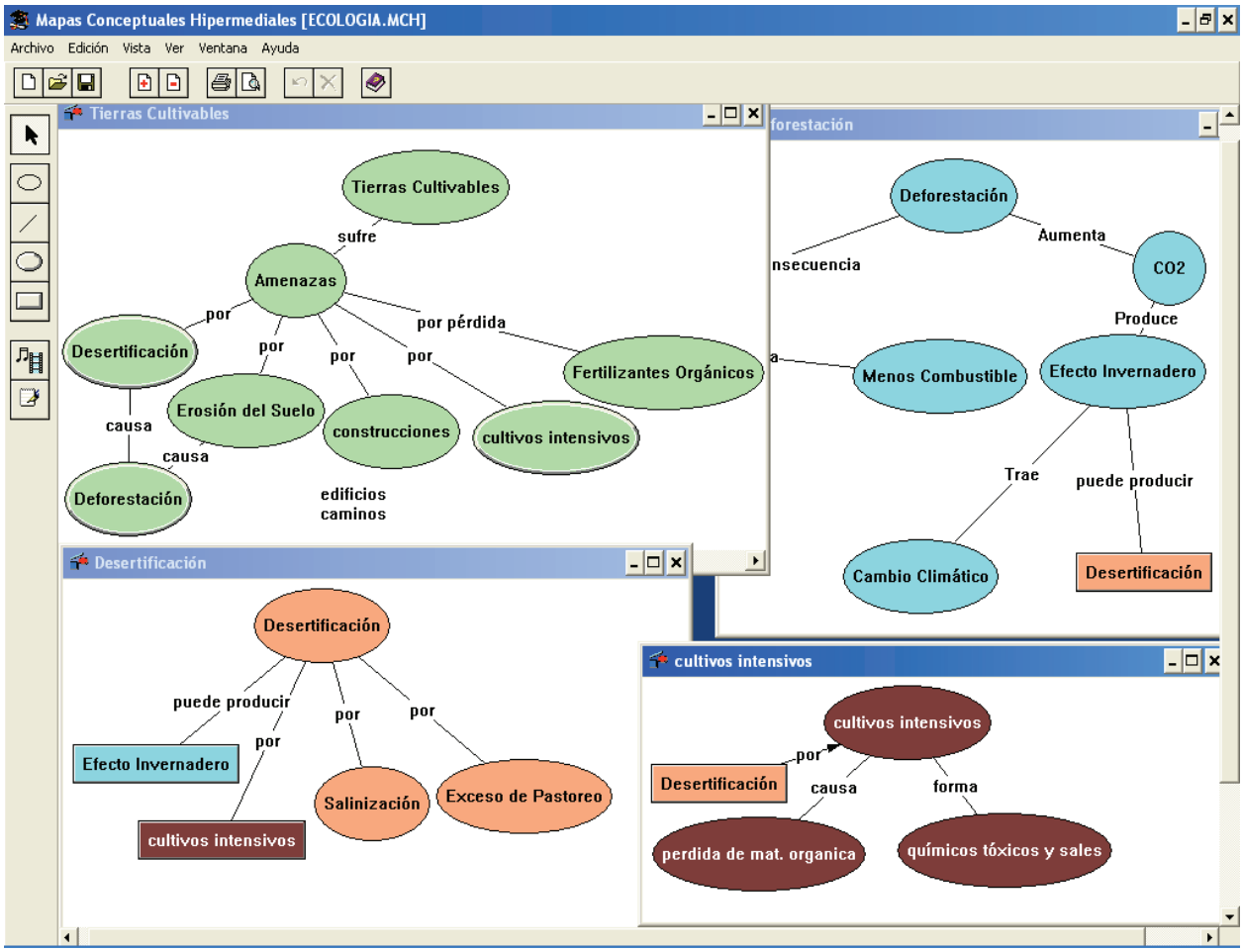


Figura 1– Vistas del MCH: Ecología

La plataforma propuesta proporciona dos modos diferenciados de trabajo: el modo lector y el modo autor. El modo lector se usa para la inspección de un MCH ya creado, visitando una o más vistas del mismo. En el modo autor se construye o modifica un MCH o se interconectan dos mapas previamente creados. El modo autor cuenta con el menú básico de cualquier aplicación que disponga de la capacidad de edición y los recursos gráficos necesarios para la creación del hipertexto. Además, ofrece herramientas gráficas propias para la creación de MCH a partir de sus componentes: concepto elipse rotulado, concepto botón elíptico rotulado, concepto botón rectangular, arco

rotulado, paleta de colores, rectángulo transparente para ejemplos. El concepto elipse rotulado genera los conceptos propios de una vista y el arco rotulado permite unir dos conceptos de un MCH formando una proposición. Estos constructores son los mismos que se proveen en los MC tradicionales. Sin embargo, dada la naturaleza hipermedial de los MCH se incorporan los siguientes constructores propios (Zanconi y otros, 1998):

- El *concepto botón elíptico rotulado*: como caso particular de concepto elipse rotulado. Por su característica de botón permite la navegación entre las vistas de un mapa. Representa el vínculo entre dos vistas a través de la relación de especificación. Estos conceptos son los que determinan la organización de un MCH en *vistas*.
- El *concepto botón rectangular*: es la representación en una vista V_i de un concepto elipse de otra vista V_j que se ha importado a V_i con el propósito de poder establecer en esta última vista una relación cruzada entre dicho concepto importado y uno propio de la vista. Al igual que en el caso del constructor anterior, el modo lector permite la navegación entre las vistas de un mapa. Se utiliza para establecer *relaciones externas* entre conceptos definidos en diferentes vistas.
- La *paleta de colores* permite asignar a cada vista un color que la identifique.
- El *rectángulo transparente*: da la posibilidad de asociar una leyenda con ejemplos a un concepto elipse para rotular terminal.

Además de los recursos específicos para el desarrollo del hipertexto, en la barra de herramientas están disponibles opciones para la incorporación de información multimedial. Esto significa que existe la posibilidad de asociar a los conceptos que son elipses terminales distintas apariencias tales como sonido, imagen, animación, vídeo, etc. Las herramientas tienen representación icónica y, básicamente, se usan siguiendo un proceso de selección y arrastre. En los casos en que corresponde asociar un rótulo, se abre un cuadro de diálogo solicitándolo. En la Tabla 1 se puede ver la representación icónica de los distintos constructores del MCH.

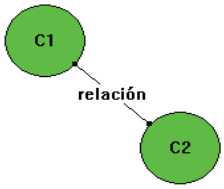
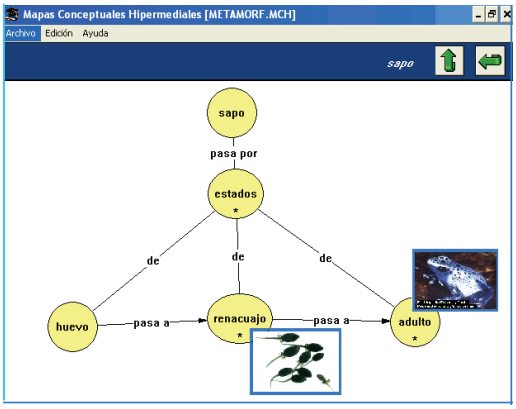
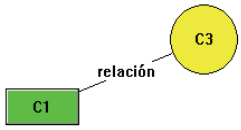
CONCEPTOS		RELACIONES		VISTAS
Terminal sin apariencia		Internas		
Terminal con apariencia				
No Terminal		Externas		
Externo				

Tabla 1 – Representación Gráfica de los Constructores del MCH

En el modo lector sólo se permite recorrer las vistas de un mapa creado. El medio provisto para la navegación son los botones: tanto los que fueron diseñados por el autor, elípticos o rectangulares, como los auxiliares, generados automáticamente por la plataforma. En cada vista, se muestra una porción del mapa y se dispone de dos botones auxiliares, uno permite la navegación de regreso a la vista previamente visitada y el otro permite acceder directamente a la vista más general (de nivel más alto) del MCH. Las elipses marcadas con un "*", distinguen los

conceptos que cuentan con apariencias multimediales extras, que en el modo lector se sobreimprimirán a la vista y desaparecerán automáticamente a solicitud del lector del mapa.

3 Descripción de la experiencia educativa

Una parte importante de esta investigación consistió en realizar una experiencia de aplicación de los MCH en campo, que permitiera comprobar y medir resultados. Para ello se optó por un trabajo interdisciplinario en cursos universitarios en el que participaron docentes-investigadores de las áreas de Ciencias e Ingeniería de la Computación, de Ciencias de la Educación y de Lenguas Extranjeras (en este caso de Lengua Inglesa). El plan de trabajo se centró en la elaboración de una metodología que incluyera la utilización de los MCH. Dicha metodología se utilizó durante el período de cursado y de la evaluación de la materia extra-curricular "Curso de Lectura Comprensiva de Textos en Inglés –Nivel 2– Orientación Ciencias Naturales".

3.1 Características curriculares de la asignatura Curso de Lectura Comprensiva de Textos en Inglés- Nivel 2 – Orientación Ciencias Naturales

Este curso universitario tiene una duración total de 2 años y está organizado en 4 niveles de un cuatrimestre cada uno. Si bien este curso no pertenece al plan de estudio de una carrera en particular, se ofrece como servicio a todos los alumnos de la institución, quienes en algún punto deben cumplir con los requisitos del Examen de Suficiencia de Idioma Inglés y cuentan con la preparación que logran en estos cursos para poder aprobarlo. Además de preparar a los estudiantes para la suficiencia, este curso tiene como objetivo capacitarlos para que puedan comprender textos de su especialidad -en el caso particular de nuestra experiencia, bibliografía para las carreras relacionadas con las ciencias naturales que se dictan en nuestra universidad, como por ejemplo biología, bioquímica, farmacia, química, agronomía, etc- en idioma inglés y de un grado de complejidad intermedia, ya que en esta experiencia piloto aplicamos la Plataforma MCH en el Nivel 2. Para lograr los objetivos, los cursos se centran en la enseñanza y aplicación de diversas estrategias de lectura comprensiva que se aplican a textos con un grado de dificultad creciente conforme se avanza en el programa (Nuttall, 1996; Wallace, 1992; Forman, 1990). Cabe señalar que el idioma de trabajo y producción de los cursos es el español. Los estudiantes sólo leen el texto en inglés y posteriormente trabajan sobre éste hasta lograr su comprensión mediante distintas técnicas y ejercicios que resuelven en español.

3.2 Diseño de la Experiencia de campo

Para el desarrollo de la experiencia se elaboró un plan de trabajo organizado en las siguientes etapas:

1. *Capacitación de los docentes del Área de Lenguas Extranjeras con la técnica MCH*: se realizaron talleres prácticos dirigidos a docentes del área donde se trabajó el tema de los aprendizajes significativos y se presentó la plataforma y los lineamientos sobre su uso.
2. *Desarrollo conjunto de la metodología*: tomando como base la metodología de construcción de MCH originalmente propuesta (Señas y otros, 1996), se trabajó con los docentes en el refinamiento de la misma, de manera de lograr un método de construcción de MCH que se adapte a la organización y las técnicas de trabajo que se desarrollan en el curso (Nuttall,1996; Wallace,1992, Forman,1990).
3. *Relevamiento del curso*: en la planificación de la experiencia se incluyó una encuesta tendiente a medir cuántos alumnos tenían conocimiento de la técnica de estudio con MC en general y cuántos tenían experiencia en el uso de computadoras.
4. *Capacitación de los alumnos del curso en el uso de la plataforma y la metodología de elaboración de los MCH*: dentro de la organización del curso, se destinaron 4 horas cátedra a la presentación de los MCH como técnica de estudio, la metodología de construcción propuesta y la Plataforma MCH.
5. *Lectura comprensiva con elaboración de MCH*: se eligieron algunos de los textos que habitualmente se analizan en el curso para que los alumnos trabajen en la producción del MCH siguiendo la metodología propuesta. La experiencia se realizó en laboratorio y los alumnos trabajaron de a pares.
6. *Evaluación de los alumnos*: para esta etapa se dividió el curso en dos grupos. La evaluación de los alumnos del primer grupo consistió en que cada uno construya, en forma individual, el MCH de los textos asignados. Los alumnos del segundo grupo fueron evaluados con la técnica convencional que consiste en la elaboración de un resumen a partir de un texto.

7. *Evaluación de los resultados*: se analizó la experiencia desde diferentes perspectivas y se obtuvieron las conclusiones que presentaremos posteriormente.

Durante el desarrollo del proyecto se trabajó en forma integrada con los docentes a cargo de la asignatura. La experiencia se prolongó por los cuatros meses de duración de la asignatura. El primer mes se trabajó fuera del aula en la capacitación de los docentes, tanto en el uso de MCH como de la plataforma. Durante este tiempo también se estudió la mejor manera de incorporar los MCH al dictado de las clases, buscando respetar los objetivos curriculares y evitar alterar el desarrollo normal de las mismas. Así se elaboró una metodología para la construcción de MCH en lectura comprensiva. Dicha metodología se utilizó en las experiencias prácticas en clase con el uso de MCH y formó parte de los conocimientos que se ponderaron en la evaluación. En la próxima sección se presenta la metodología en detalle.

3.2.1 Metodología para la construcción de MCH en lectura comprensiva

Como resultado de la segunda etapa de la experiencia, se elaboró una metodología apta para guiar a los estudiantes en la construcción del mapa y de tal forma permitir a los docentes evaluar la comprensión del texto por parte de los alumnos. Un punto importante a tener en cuenta es que se debieron respetar las técnicas que se venían aplicando en el dictado del curso, como por ejemplo reconocimiento de patrones de organización de un texto, marcado de ideas principales y secundarias, determinación de dispositivos de cohesión y coherencia, etc. (Vitturini y otros, 2002). El conjunto de pasos propuestos incluye:

1) Tareas a realizar antes de la lectura:
   a) Plantear el propósito de la lectura: es decir, lograr la comprensión del texto completo.
   b) Predecir el contenido del texto: esta técnica se utiliza para comenzar la mayoría de los ejercicios de lectura, se trata de utilizar la información que rodea al texto en sí –imágenes, gráficos, títulos, etc.– y el conocimiento previo que trae el lector sobre el tema, para iniciar la lectura con algunas ideas en mente. Resulta de mucha utilidad para la posterior comprensión del texto.
2) Tareas a realizar durante la lectura:
   a) Seleccionar las ideas principales de cada párrafo.
   b) Reconocer los patrones de organización del texto.
   c) Reconocer los dispositivos de cohesión: marcadores de discurso y referentes.
   d) Inferir el vocabulario desconocido.
3) Tareas a realizar después de la lectura:
   a) Crear un MCH que refleje una comprensión acabada del texto.
      i. A partir de las ideas principales, seleccionar los conceptos más relevantes que se desarrollan en el texto.
      ii. A través del uso de la plataforma definir una vista auxiliar con todos los conceptos elegidos.
      iii. Estimar el número de vistas a usar. La cantidad de conceptos definidos dará una idea general del número de vistas necesarias. Como regla práctica se aconseja entre 7 ± 2 conceptos por vista.
      iv. Jerarquizar los conceptos y clasificarlos en conceptos botones no terminales y conceptos terminales.
      v. Distribuir los conceptos en las distintas vistas definidas.
      vi. Comenzar la construcción del MCH con los conceptos y según las decisiones tomadas.
      vii. Establecer las relaciones entre los conceptos de una misma vista.
      viii. Hacer corresponder a cada uno de los patrones de organización encontrados en el texto el patrón correspondiente en el MCH.
      ix. Analizar las posibles relaciones cruzadas. Una vez determinadas, si existen, importar los conceptos necesarios en forma de conceptos botones externos.
   b) Refinar el mapa a partir de una nueva lectura del texto.

3.3 Resultados de la experiencia con MCH

Luego, se realizó una evaluación del producto terminado desde las perspectivas sintáctica y semántica y se cuantificaron los siguientes puntos para cada uno de los MCH elaborados:

- Número de vistas
- Número de conceptos
- Grado de corrección de las relaciones internas
- Existencia de relaciones externas

- Grado de corrección de las proposiciones que se obtienen a partir del mapa

Los textos que se trabajan durante el curso van aumentando en complejidad. La necesidad de definir más conceptos y de distribuirlos en distintas vistas surgió naturalmente. No se observaron falencias importantes por parte de los alumnos para jerarquizar los conceptos en vistas. Sí se pudieron detectar distintos grados de dificultad en los estudiantes para identificar los conceptos relevantes de un texto. Algo similar ocurrió al momento de plantear las relaciones. Se pudo observar que a la mayoría de los alumnos les resultó simple definir las relaciones entre conceptos de una misma vista, y en general se vio una tendencia a no representar las relaciones cruzadas.

3.3.1 Análisis funcional de la herramienta

En el transcurso de la experiencia se observó que el uso de la plataforma no presentó dificultades desde lo funcional, ni para los docentes ni para los estudiantes. A continuación se presentan los resultados observados según dos puntos de vista diferentes: desde lo didáctico y desde lo operacional.

Desde lo didáctico, se pudo observar que en el grupo que trabajó con MCH, las producciones resultantes respondieron de mejor manera a la consigna de elaborar un resumen. Los resultados presentados por los estudiantes que no trabajaron con MCH se acercaron más a un modelo de traducción convencional, con marcada inclinación a la traducción literal. Obviamente la necesidad de construir el MCH y de aplicar la metodología propuesta conduce de mejor manera al trabajo de comprensión de un texto.

Desde lo operacional, se pudo comprobar que el trabajo en el Ambiente MCH resultó enriquecedor y su uso no presentó dificultades, muy por el contrario, reflejó el grado de amigabilidad de la herramienta y lo motivador de la estrategia. A partir de la experiencia práctica en el laboratorio, se advirtió que sería útil incorporar a la plataforma nuevas funcionalidades que colaboren con el autor en la tarea de construcción del mapa, indicándole la presencia de posibles errores. Estas funcionalidades estarían activas únicamente en el modo autor y cumplirían el rol de controladores sintácticos. Dependiendo del tipo de supervisión automática que el docente desee que la plataforma realice, aparecen dos casos:

- En modo advertencia, cuando detecta una situación irregular e indica al autor del mapa la posibilidad de un error e informa la naturaleza del mismo.
- Como un control estricto, que no autoriza la operación.

Se propone la incorporación al Ambiente MCH de las siguientes herramientas:
- Controlador Ortográfico automático.
- Controlador automático de conceptos repetidos (ya que en un mapa correcto, cada concepto debe aparecer representado una única vez como concepto propio.
- Diccionario Inglés-Castellano (para uso en cursos de lectura comprensiva)

El controlador ortográfico cumplirá el rol de señalar posibles errores tipográficos en los rótulos, actuará como advertencia, dejando al autor la decisión final de corrección, siguiendo la opción renombrar disponible para conceptos y relaciones, o sus omisiones.

El controlador de conceptos repetidos es importante en el entorno MCH y colaborará en la tarea de evitar mapas con errores sintácticos. En el momento en que se crea un nuevo *concepto elipse para rotular* o *concepto botón elíptico para rotular* si se detecta que ya ha sido definido otro con el mismo rótulo no permitirá que se confirme la operación. Existen situaciones en las que se necesita referenciar al mismo concepto en más de una vista. En estos casos, el autor deberá decidir en cuál de ellas, si existe una, es en la que mejor queda representado como concepto propio. En las otras vistas deberá definirlo como importado y vincularlo con otro concepto por medio de una relación externa. Este tipo de relación enriquece el conocimiento y favorece la presentación de un concepto desde diferentes perspectivas durante su lectura hipermedial.

La duplicación de conceptos en un mapa a través de definirlos más de una vez con rótulos que son sinónimos, tiene como efecto el mismo error conceptual que repetir conceptos usando rótulos idénticos. Sin embargo, el problema de determinar si dos conceptos son o no sinónimo, no tiene solución computacional en este entorno, ya que la respuesta depende del significado que tiene cada uno de ellos en el contexto en el que está siendo utilizado. Por esta razón no sería correcto que la plataforma no autorice la creación de un concepto si el controlador detecta un

sinónimo ya definido. Como un mecanismo de ayuda ofrecido al autor le advertirá esta situación, de modo que éste pueda decidir si debe reemplazarlo por un concepto importado.

Con relación al control de errores ortográficos, será del tipo de los controles que habitualmente se encuentran en editores convencionales. Podrá ser activado voluntariamente por el autor o trabajar en línea. Si está activo en línea, después de la confirmación de nombre de concepto o relación en el cuadro de diálogo, se activará el control que buscará en el diccionario castellano indicando si se encontró o no el término en el mismo.

4 Conclusiones

A partir del análisis del contenido curricular de la materia Curso de Lectura Comprensiva de Textos en Inglés – Nivel II se observó la posibilidad de incluir la técnica de estudio MCH dentro del desarrollo del curso. El esfuerzo de llevar adelante una experiencia interdisciplinaria de estas características en un curso universitario fue importante porque permitió la definición de una nueva metodología que fortalece el uso de MCH como técnica de estudio. Además, de la evaluación presencial surgió la necesidad de encarar un trabajo de reingeniería sobre la plataforma que permitiera rediseñar algunas de las operaciones fundamentales de modo que se incluyeran nuevos controles, ayudas y herramientas que colaboren en la tarea de construcción de un MCH. Estos resultados obtenidos en el marco del LIDInE, por un lado, abren nuevas posibilidades para desarrollos de tesis de Licenciatura en Ciencias de la Computación, y por otro, enriquece el conjunto de herramientas computacionales que están fuertemente fundamentadas en tecnologías educativas y que son aptas para el uso en educación basada en la Web. Además, se pudo medir el uso de MCH en el desarrollo del curso, obteniendo resultados favorables desde lo didáctico. De la comparación de las producciones de MCH obtenidas y las elaboradas por el grupo testigo, se pudo corroborar que los resultados del primero se apartaron significativamente de la mera traducción literal y respondieron de mejor manera al objetivo general del curso.

5 Agradecimientos

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Referencias

D. P. Ausubel, J. D. Novak. *Educational Psychology: A Cognitive View*. 2nd Ed. New York: Holt, Rinerhart and Winston. 1978.

Bahar,G. *Bilingual Knowledge Maps: Study Strategy Effects. En: Concept Maps: Theory, Methodology, Technology.* Proceedings of the First International Conference on Concept Mapping, Pamplona, España: Unversidad Pública de Navarra, Vol 1. 2004

Forman, D., Donoghue, F., Abbey, S., Cruden, B. and Kidd, I. *Campus English* A study skills course for university students. MacMillan Publishers. 1990

Garzzoto, Mainetti y Paolini: *Hypermedia Design, Analysis and Evaluation Issues*. Communications ACM. August 1995.

Isakowitz, T., Stohr, E. and Balasubramanian, P. *RMM: A methodology for Structured Hypermedia Design*. Communications ACM. August 1995.

Malet, A. y Señas P. *Los Mapas Conceptuales Hipermediales y la construcción de conocimiento*. V Conferencia Internacional de Ciencias de la Educación. Cuba. 1999.

Marchionini, G. y Crane, G., *Evaluating Hypermedia and Learning: Methods and Results from the Perseus Project*. ACM Transactions on Information Systems. Vol 12. N1. Enero 1994, pp 5-34.

Martig, S. y Señas, P. *Herramientas para la construcción de conocimiento en ambientes de aprendizaje abiertos: Construcción y Visualización del Grafo Integrador de un MCH*. VI CACIC. Argentina. 2000.

Martig, S. y Señas, P. *Información contextual en ambientes MCH*. VII CACIC. Argentina. 2001.

Martig, S y Señas, P. *Grafo Integrador Anidado de un MCH* VII CACIC. Argentina. 2001.

Meeting of the National Association for Research in Science Teaching. Atlanta. USA. 1993.

Novak, J. D. y Gowin, D. *Learning how to learn*. New York. Cambridge University Press. 1984.

Novak, J. D. *Metalearning and metaknowledge strategies to help students learn how to learn*. *Cognitive Structure and Conceptual Change*. New York. Academic Press.1985.

Novak, J. D. Learning , creating and using knowledge . New York. 1998

Nuttall, C. *Teaching Reading Skills in a Foreign Language* Heinemann. New Edition. 1996.

Ontoria, A. *Mapas Conceptuales: Una técnica para Aprender*. Narcea S.A. de Ediciones. Madrid. 1992.

Perkins, D. *La escuela inteligente*. Barcelona. Gedisa. 1995.

Sanchez J. *Concept mapping and educational software production*. 66th. Annual

Sanchez J. *Metalearning and metaknowledge strategies to produce educational software*. Amsterdam Elseiver Science Publishers B. V. 1993.

Señas, P.y otros: *Hypermedial Conceptual Mapping: A Development Methodology*. 13th International Conference on Technology and Education. University of Texas at Arlington, Departament of Computer Science an Engineering. New Orleans 1996.

Señas, P. y Moroni, M. *Computing Environments For Metalearning:Interconnecting Hypermedia Concept Maps*. ED-MEDIA2000. Canada. 2000.

Señas, P y Moroni, N. *Learning Object semantic description for enhancing Reusability*. Journal of Computer Science and Technology. Vol 5. 2005.

Vitturini, M., y otros, *Plataforma MCH orientada a la Lectura Comprensiva de Textos*. VIII CACIC. Argentina. 2002.

Zanconi, M. y otros *Tecnología computacional y meta-aprendizajes*. RIBIE-98. Brasil. 1998.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

MAPAS CONCEPTUALES Y APRENDIZAJE DE MATEMÁTICAS

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Resumen. El presente trabajo versa sobre la importancia que tienen los mapas conceptuales para guiar al docente en su actuación en el aula y contribuir con el desarrollo de capacidades de pensamiento en los alumnos. Se presenta una experiencia educativa en la que los mapas conceptuales en el proceso de enseñanza y aprendizaje de las matemáticas son considerados como una importante herramienta para el logro de aprendizajes significativos, constructivos y por descubrimiento, desde las posturas de Ausubel, Piaget y Bruner, respectivamente. Se hace énfasis en que los mapas que el profesor elabora le sirven como guía para su enseñanza en el aula y permiten en los estudiantes la percepción de elementos asequibles a su intelecto, la representación mental o imaginación y la conceptualización (etapas fundamentales del aprendizaje). De esta manera se facilita la puesta en marcha de procesos de pensamiento tanto inductivos como deductivos desarrollando así la ejecución intelectual en los estudiantes: sus capacidades cognitivas. Se presentan, además, algunos resultados importantes como producto de la integración de mapas conceptuales en la actividad didáctica del docente durante un curso de Cálculo a nivel universitario.

1 Introducción

Como es muy bien sabido, el contenido de las matemáticas es de gran importancia, entre otros aspectos, por la aplicación en la ciencia, en la tecnología y en contextos de la vida cotidiana. Pero además, las matemáticas, como otros contenidos, tienen un gran valor educativo a todos los niveles ya que permiten el desarrollo del pensamiento. Sin embargo, a pesar de lo anterior, dirigiendo la vista a las instituciones educativas, tanto de niveles básicos como de niveles universitarios, se aprecian y se distinguen situaciones difíciles. Hoy en día existen, en todo lo largo y ancho del mundo, problemas en torno a la enseñanza y el aprendizaje de este contenido. Quizás esta realidad educativa ha aumentado el interés por emprender, desde diferentes posturas, estudios que den una alternativa o guía para la enseñanza y el aprendizaje de las matemáticas.

En el marco del paradigma cognitivo en educación, la didáctica de las matemáticas es entendida como una manera o maneras particulares de proceder en el aula para contribuir con el aprendizaje. Al mismo tiempo, el paradigma cognitivo considera que el aprendizaje de las matemáticas implica el desarrollo de varias capacidades y destrezas, es decir, el desarrollo de la cognición del aprendiz.

En este orden de ideas, como producto de la reflexión sobre diferentes maneras de proceder en el aula, se ha encontrado que los mapas conceptuales representan una herramienta didáctica muy útil dentro del proceso de enseñanza y aprendizaje de las matemáticas. En las siguientes líneas se detallará el papel de los mapas conceptuales como guía para el profesor y la importancia de estas estructuras para el desarrollo de los procesos de pensamiento.

2 Mapas y aprendizaje: desarrollo del pensamiento

¿Por qué el uso de mapas conceptuales para las clases de matemáticas? La elaboración de mapas por parte del docente y la utilización de éstos en las aulas permite un aprendizaje de los contenidos de manera constructiva y significativa, así como un adecuado almacenamiento del material en la estructura cognitiva del estudiante para disponer de ellos cuando se requiera (Ausubel, 1988). Un aprendizaje de calidad de las matemáticas se aprecia cuando los contenidos son utilizados correctamente al momento de solucionar problemas específicos de matemáticas o problemas de la vida cotidiana.

La utilización de mapas conceptuales en el aula junto con un conjunto de estrategias didácticas permite el desarrollo cognitivo del aprendiz. Esto, a su vez, representa un adecuado almacenamiento de contenidos en la estructura cognitiva del estudiante que implica un desarrollo del pensamiento. En este sentido, la actuación del docente guiada por mapas conceptuales permite una intervención cognitiva. Las matemáticas y los mapas se consideran medios para lograr el desarrollo de capacidades y destrezas cognitivas (Román, 1988).

2.1 Mapas, docentes y alumnos

Es de esperarse que surjan las siguientes preguntas: ¿cómo intervienen los mapas conceptuales en un curso de cálculo?, ¿quién elabora los mapas?, ¿se reduce una clase de matemáticas a la presentación de mapas conceptuales?, ¿cómo se logra el desarrollo del pensamiento utilizando como herramienta un conjunto de mapas conceptuales?, ¿cómo interactúan los mapas, el docente y los alumnos?. En las siguientes líneas se da respuesta a las preguntas anteriores y se detalla, sobre todo, las características de la actividad del profesor al integrar mapas conceptuales a su labor docente.

Como se mencionó anteriormente, el profesor elabora sus mapas conceptuales del contenido de las matemáticas en donde aparecen conceptos con diferentes niveles de generalidad, gráficas o imágenes asociadas a los conceptos y ejemplos concretos de éstos. Las gráficas o imágenes contribuyen a la visualización de los conceptos: al aprendizaje de las matemáticas (De Guzmán, 1996).

Las clases no consisten en presentar a los alumnos en un inicio los mapas que el profesor elabora. Los mapas hechos por el profesor representan una guía propia para su actuación docente en el aula con los alumnos. Se trata de presentar a los alumnos poco a poco la información que aparece en los mapas tratando de ir desde lo particular hasta lo general, desde luego, ampliando y enriqueciendo la información. En otras palabras, partir desde la información colocada en la parte inferior de los mapas hasta la información de la parte superior de éstos. La idea es presentar información particular asequible al intelecto de los alumnos para ser percibida; posteriormente, con el apoyo de imágenes y/o representaciones gráficas, llegar a la presentación de los conceptos. El partir desde lo particular hasta lo general promueve la realización de procesos de pensamiento inductivo lo que significa un desarrollo o intervención cognitiva (Feuerstein, 1995).

El trabajo intelectual que el profesor realiza al elaborar sus mapas que le servirán de guía significa considerar el proceso aprendizaje-enseñanza, es decir, averiguar como aprende el aprendiz para en función de ello diseñar la enseñanza. Es importante mencionar que las etapas de percepción, representación y conceptualización, son consideradas como las etapas básicas del aprendizaje (Román, 1988). Los mapas conceptuales guían para propiciar dichas etapas en el aula.

Al fomentar la percepción, la representación y la conceptualización, siguiendo este orden, se pone en práctica el pensamiento inductivo. Posteriormente el profesor puede presentar sus mapas o construir éstos con los alumnos para promover los procesos de pensamiento deductivo partiendo de lo general hasta lo particular. De esta manera, también, se impulsa a los alumnos a que practiquen la elaboración de mapas. Habiendo transcurrido cierto tiempo del curso los alumnos realizan sus propios mapas con la supervisión del profesor quién actúa como mediador del aprendizaje favoreciendo el desarrollo del pensamiento (Vygotsky, 1979) y permitiendo aprender a aprender (Novak, 1988).

Tal como lo explica Ausubel, los procesos de pensamiento inductivo y deductivo son potenciados al disponer la información respetando las jerarquías conceptuales, logrando aprendizajes subordinados y supraordenados, partiendo desde lo particular hasta lo general y viceversa (Ausubel, 1976). Desde la óptica de Bruner y la teoría sobre el aprendizaje por descubrimiento, el partir desde un sistema enactivo hasta un sistema simbólico permite el desarrollo de procesos inductivos (Bruner, 1988). Como una interpretación particular de las ideas Piagetanas, se considera que al contraponer hechos con conceptos y conceptos con hechos se llevan a cabo procesos inductivos y deductivos contribuyendo al aprendizaje constructivo (Piaget, 1979).

Es importante mencionar que los mapas conceptuales (Novak, 1998) desempeñan en el aula una función clave para representar los conocimientos. Los mapas conceptuales son un buen apoyo para el profesor. Ayudan a organizar el conocimiento para enseñarlo (Novak, 1998) pero también ayudan a los alumnos en su desempeño escolar al tener aprendizajes de calidad (no memorísticos). Las figuras 1 y 2 en las siguientes páginas muestran algunos ejemplos de mapas conceptuales construidos e integrados al proceso de enseñanza y aprendizaje de matemáticas durante un curso de cálculo. Por razones de espacio no se incluyen más mapas en este trabajo. Es importante señalar que la enseñanza y el aprendizaje de las matemáticas no sólo se centran en conceptos, también se debe prestar mucha atención a los ejercicios y problemas así como al desarrollo de habilidades para resolverlos.

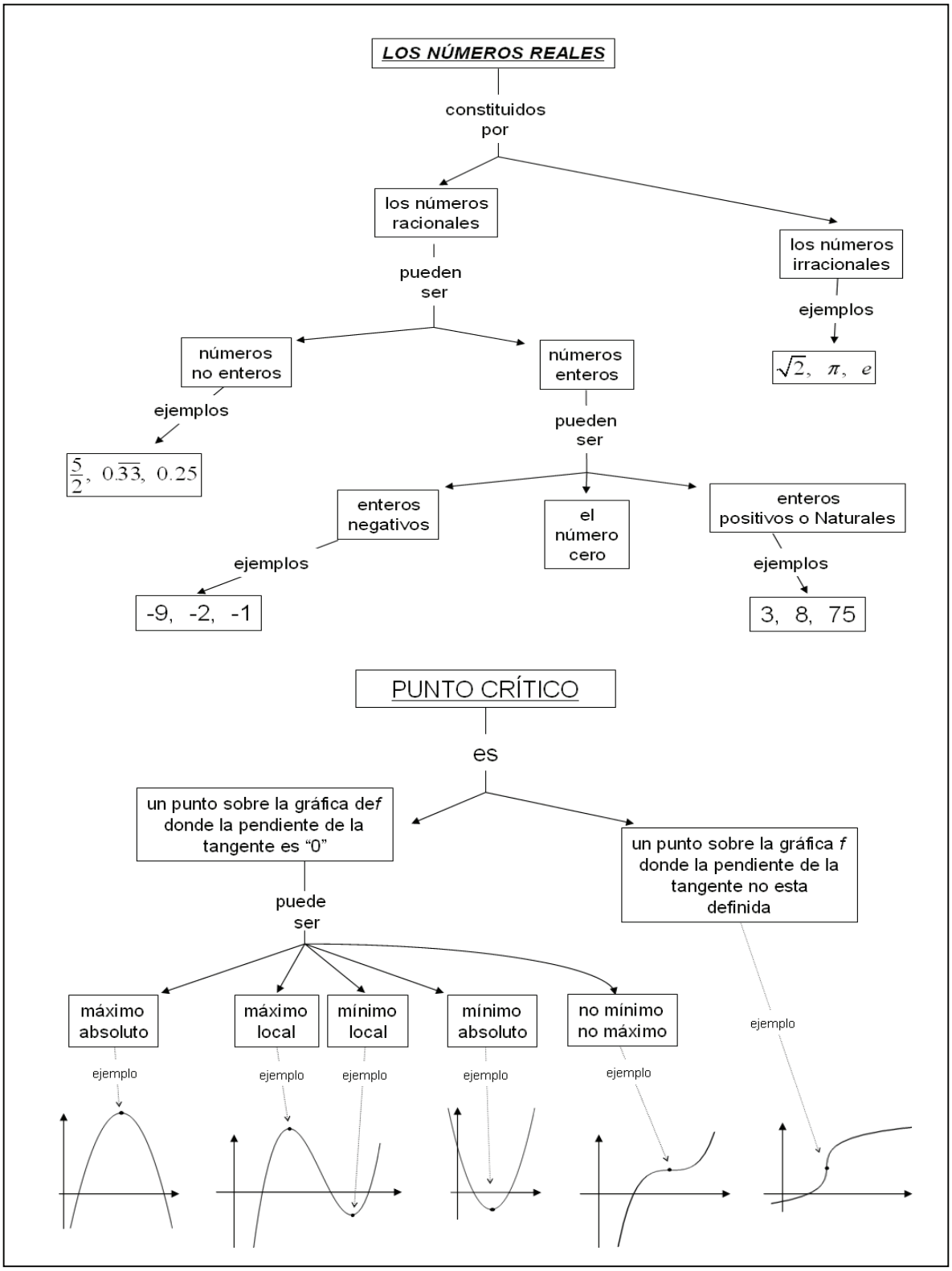


Figura 1. Mapas conceptuales "Los Números Reales" y "Punto Crítico"

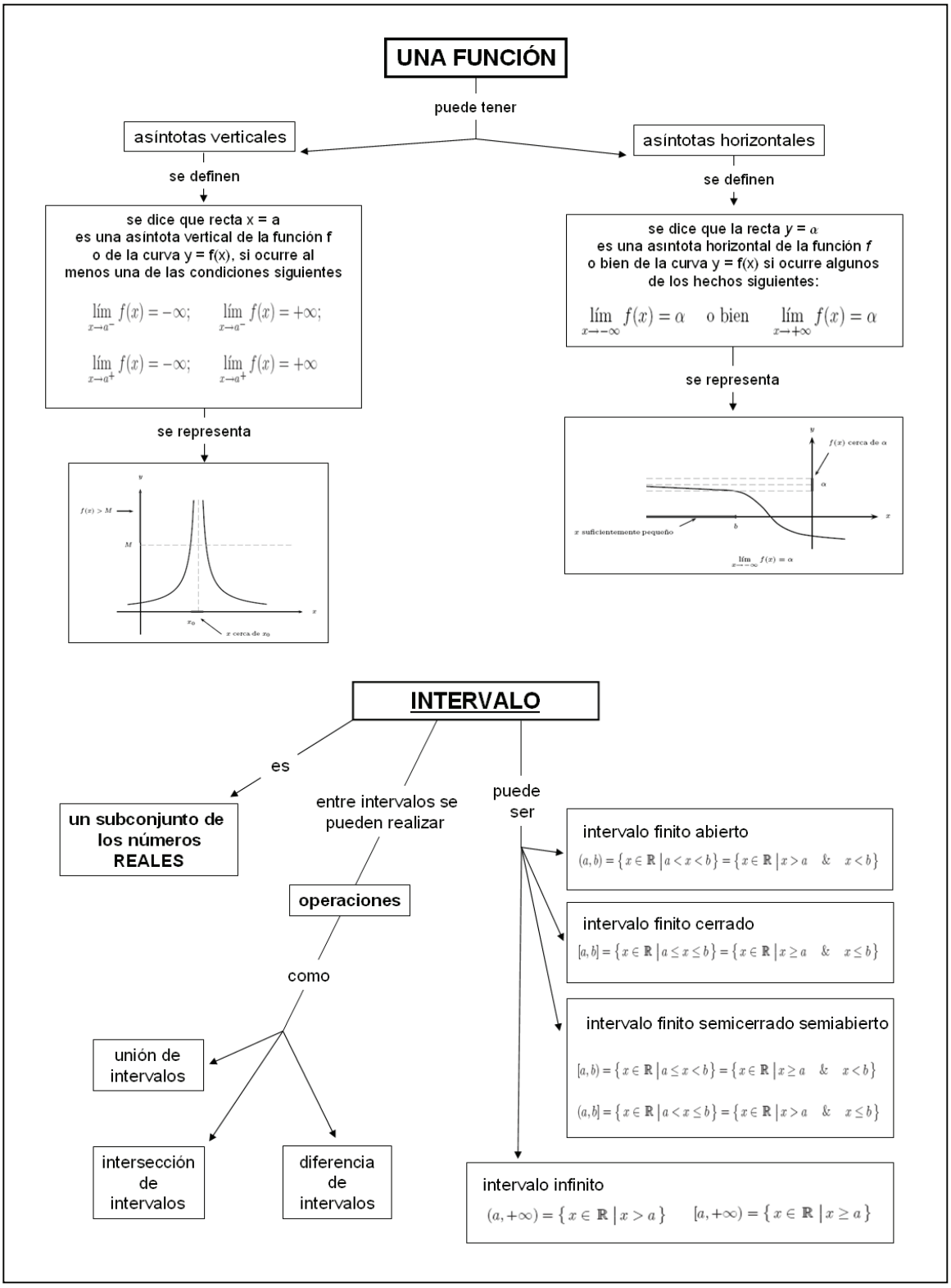


Figura 2. Mapas conceptuales: "Una Función" e "Intervalo"

Por lo anterior, los mapas conceptuales no sólo contemplan conceptos, también son importantes los mapas que muestran aspectos sobre los procedimientos para resolver problemas.

2.2 Objetivos que se pretenden con la elaboración y uso de mapas

Con la utilización de mapas conceptuales en el aula y con un conjunto de estrategias (como brevemente se han descrito) se favorece, en términos generales, el desarrollo cognitivo del aprendiz. En particular, con esta forma de proceder se busca el desarrollo de: 1) las destrezas de Inducción y Deducción consideradas como parte de la capacidad Razonamiento Lógico y 2) las destrezas Situar, Localizar y Expresar Gráficamente, consideradas como parte de la capacidad Orientación Espacial. Cabe señalar que al desarrollar los procesos cognitivos implícitos en las matemáticas se desarrolla el pensamiento (De Guzmán, 1999).

2.3 Metodología investigadora

Con la actuación del profesor orientada con los mapas que elabora y con el uso y realización de mapas por parte del alumno ¿se logra un desarrollo del pensamiento sustancial en el estudiante?, ¿se logra un aprendizaje de las matemáticas? Las siguientes líneas versarán sobre la metodología investigadora que se ha seguido en diferentes etapas de experimentación.

Se utilizó un diseño factorial 2x2 considerando dos factores: un factor de medidas independientes con dos valores o niveles y un factor de medidas repetidas también con dos valores. El factor de medidas independientes es el tratamiento cuyos niveles son: Grupo experimental con tratamiento y grupo control sin tratamiento. El factor de medidas repetidas lo forman las fases de aplicación con dos niveles: la fase pre-test (puntuaciones antes de iniciar el entrenamiento o curso) y la fase post-test (puntuaciones una vez que finalizó el entrenamiento o curso).

Se seleccionó un grupo de estudiantes al cuál se aplicaron las pruebas pre-test que miden el Razonamiento Numérico, Razonamiento Abstracto y Relaciones Espaciales (Test de aptitudes diferenciales Dat-5). Una vez que se analizó la información se conformaron dos muestras: la muestra grupo control y la muestra grupo experimental. Antes de iniciar el entrenamiento se realizaron análisis previos (se aplicaron las pruebas Student´s **t** y la Suma de Rangos de Wilcoxon a la información) que permitieron afirmar que los grupos, tanto experimental como control, fueron homogéneos, es decir, no existió entre ellos diferencias estadísticamente significativas en el momento "pre" en cuanto al Razonamiento Numérico, Razonamiento Abstracto y Relaciones Espaciales.

El grupo control inició con un curso ordinario (curso tradicional) de la asignatura "Cálculo I" y el grupo experimental con un curso de la misma asignatura pero con un proceso de enseñanza-aprendizaje apoyado con mapas conceptuales. El curso en ambos grupos tuvo una duración de tres meses tomando en consideración las características de la programación de la Universidad Autónoma Metropolitana (UAM) en la ciudad de México, institución en donde se ha realizado la investigación educativa.

Durante el curso, en ambos grupos, se tuvieron un determinado número de sesiones con carácter obligatorio (1.5 horas de lunes a viernes). Además, para ambos grupos se contempló un número extra de sesiones individuales para todos los alumnos que las solicitaron; fueron sesiones de asesoría y el número y tiempo de duración de ellas dependió del número de alumnos que las solicitaron. Al finalizar el curso (entrenamiento) se aplicaron las pruebas post-test a todos los estudiantes, tanto del grupo experimental como del grupo control.

Para valorar las diferencias en los resultados obtenidos entre la fase pre-test y la fase post-test, entre los grupos experimental y control, se llevó a cabo un análisis de los datos obtenidos. A éstos se aplicaron las siguientes pruebas: Student´s **t** (Prueba paramétrica) y Rangos Signados de Wilcoxon (Prueba no paramétrica). En esta investigación educativa se tuvieron las siguientes hipótesis fundamentales:

Si se imparte a un grupo de estudiantes universitarios (grupo experimental) un curso de la asignatura "*Cálculo I"* con un proceso de Enseñanza-Aprendizaje apoyado con mapas conceptuales y se comparan los resultados obtenidos con los alcanzados por otro grupo (grupo control) de características homogéneas al cual se le imparte la misma asignatura de una forma tradicional:

1. se observará un aumento significativamente superior del Razonamiento Numérico —medido con el Test "Dat-5"— en los sujetos del grupo experimental con respecto a los del grupo control.
2. se observará un aumento significativamente superior del Razonamiento Abstracto —medido con el Test "Dat-5"— en los sujetos del grupo experimental con respecto a los del grupo control.
3. se observará un aumento significativamente superior de Relaciones Espaciales —medido con el Test "Dat-5"— en los sujetos del grupo experimental con respecto a los del grupo control.

2.4 Resultados

Antes de exponer los resultados que se han encontrado al llevar acabo las actividades didácticas descritas anteriormente, cabe señalar que en pasadas ocasiones, en etapas de experimentación anteriores, utilizando instrumentos como el Test de factor "g" de Cattell o el Test de Raven que miden la inteligencia general (el CI, cociente intelectual), los resultados han sido alentadores. Habiendo procesado estadísticamente la información se observaron diferencias estadísticamente significativas sólo en el grupo experimental para un nivel de confianza del 99% entre pre y post. Se afirmó que existió evolución significativa del C.I. en el grupo experimental debida, principalmente, por el efecto de la aplicación de una didáctica o un actuar docente guiado por mapas conceptuales y la teoría que los sustenta.

En esta investigación fueron utilizados instrumentos tanto cuantitativos como cualitativos para llevar a cabo una evaluación del proceso de enseñanza con una didáctica guiada con mapas conceptuales. Los instrumentos que se emplearon para realizar el registro cualitativo fueron: un diario de cada uno de los alumnos, un diario del docente y las evaluaciones parciales sobre el contenido realizadas durante el curso. La información que plasmaron los estudiantes en estas evaluaciones reflejó aspectos cualitativos del aprovechamiento académico entendido como el nivel de aprendizaje que tuvieron los estudiantes de los contenidos de la asignatura y sobre el desarrollo de las capacidades y destrezas. Además, un análisis de toda la información plasmada en estos instrumentos permitió concluir lo siguiente:

- Los alumnos expresan el énfasis que ha hecho el profesor en la presentación de información particular (ejemplos) que sustenta la introducción de los conceptos. Califican esta forma de proceder como apropiada porque contribuye al aprendizaje de la teoría del cálculo en una forma no memorística. Los comentarios de los alumnos hacen referencia, en forma implícita, de la importancia de la percepción de contenidos asequibles a su intelecto como primera etapa de procesos inductivos.
- Los alumnos comentaron que las imágenes o representaciones gráficas sobre la información particular contribuyó a la comprensión de los conceptos más complejos. Hablan sobre la importancia de las representaciones mentales o gráficas (una imagen dice más que mil palabras).
- Los alumnos consideran importante el conocer los mapas conceptuales que el docente elabora una vez que ha presentado los aspectos prácticos y teóricos. Expresan que esta actividad les motiva a construir sus propios mapas sobre el contenido del curso desarrollando así su pensamiento.
- Los alumnos señalan que, con la construcción de mapas conceptuales, continúan con la práctica de sus procesos de pensamiento de lo particular a lo general y de lo general a lo particular (procesos inductivos y deductivos).
- Los estudiantes hablan sobre uno de los aspectos importantes del curso: hacen referencia a que han comprendido la teoría y no la han memorizado. Esto gracias a la construcción de mapas. Algunos alumnos expresaron que ciertos conceptos y procedimientos para resolver problemas, aprendidos en cursos anteriores, los recordaban pero sin saber el sustento: el porqué y el para qué de éstos.

Para llevar a cabo el registro cuantitativo se utilizaron, como se mencionó anteriormente, los siguientes instrumentos: Test de aptitudes diferenciales Dat-5 que mide el Razonamiento Numérico, Razonamiento Abstracto y Relaciones Espaciales. Los resultados obtenidos permitieron verificar las hipótesis de la investigación. Habiendo procesado la información del Dat-5 que mide el Razonamiento Numérico para el grupo control y experimental, se observaron diferencias estadísticamente significativas sólo en el grupo experimental para un nivel de confianza del 99% entre pre y post. El procesamiento de la información del Dat-5 que mide el Razonamiento Abstracto y el procesamiento de la información del Dat-5 que mide Relaciones Espaciales revelaron, también, diferencias estadísticamente significativas para un nivel de confianza del 99% entre pre y post. Por lo anterior se pudo afirmar

que existió evolución significativa del Razonamiento Numérico, del Razonamiento Abstracto y de Relaciones Espaciales en el grupo Experimental. Este aumento se explica, principalmente, por el efecto que tiene el integrar, en el proceso de enseñanza-aprendizaje de un curso de cálculo, mapas conceptuales como herramientas para el desarrollo de destrezas y capacidades cognitivas en los estudiantes. Es importante resaltar que las ideas teóricas que sustentan a los mapas conceptuales, principalmente las que explican las formas de actuar con éstos, también tienen un efecto en los cambios que los alumnos han experimentado.

3 Conclusiones

En esta investigación el aprendizaje de las matemáticas es entendido por el docente como un desarrollo de capacidades y destrezas. En este sentido, con la información estadística obtenida se puede concluir que esta forma particular de actuar en el aula, guiada por la información de los mapas conceptuales que el profesor elabora, contribuye a desarrollar la cognición en el estudiante. La puesta en marcha de procesos inductivos y deductivos implícitos en las matemáticas desarrolla la ejecución intelectual: el pensamiento. Las aportaciones de los estudiantes, en los diferentes instrumentos, en torno a lo que han aprendido, proporcionan una evidencia de ese desarrollo.

El docente, al iniciar los temas del curso con información particular y apoyándose en representaciones gráficos e imágenes para llegar a los conceptos genera en el aula una atmósfera que propicia las actividades mentales en los estudiantes. Los estudiantes no se concretan en ser observadores pasivos, desde un principio perciben, representan y conceptualizan. Esto a su vez genera motivación entre ellos. Los comentarios de los alumnos muestran una evidencia de la motivación como motor para el desarrollo de capacidades y destrezas.

El alumno tiene un Aprendizaje Significativo al construir la estructura cognitiva, es decir, al desarrollar el pensamiento. Este desarrollo se obtiene al vincular la nueva información a los conceptos que ya se tienen: cuando el aprendiz encuentra sentido a lo que aprende. Gracias a la guía que los mapas conceptuales proporcionan al docente, los procesos implicados en su construcción —proceso inductivo entendido como un Aprendizaje Subordinado y el proceso deductivo entendido como un Aprendizaje Supraordenado— contribuyen al desarrollo cognitivo.

El actuar del docente permite un aprendizaje constructivo cuando el alumno contrapone conceptos con hechos y hechos con conceptos, cuando parte de información particular percibida hasta la elaboración de generalidades. Además, durante la elaboración por parte del alumno de mapas conceptuales guiada por el profesor, se pone en marcha un pensamiento concreto, un pensamiento imaginativo y un pensamiento abstracto, permitiendo de esta manera un aprendizaje por descubrimiento.

Los mapas conceptuales no son una manera distinta de disponer o acomodar los contenidos. Los mapas representan una herramienta poderosa para desarrollar destrezas y capacidades cognitivas: para desarrollar el pensamiento. Detrás de los mapas conceptuales esta un cuerpo teórico riguroso que los sustentan. Enseñar en el aula con una didáctica apoyada en mapas conceptuales contribuye al aprendizaje de contenidos, pero la construcción de mapas y su puesta en marcha en el aula requiere de una reflexión profunda por parte del docente. En este orden de ideas la enseñanza toma matices especiales y diferentes con relación a las formas tradicionales de proceder en el aula.

El terreno universitario necesita de nuevas investigaciones que contemplen los procesos de aprendizaje y enseñanza. Investigaciones para el enriquecimiento del conocimiento pedagógico que conjuguen: aprendices, docentes, contenidos y tecnología. En la actualidad, en la Universidad Autónoma Metropolitana de la ciudad de México, profesores de matemáticas se encuentran construyendo, como apoyo para los cursos, un portal de matemáticas en Internet llamado "*CANEK*"que se puede encontrar en la página *http://canek.uam.mx*. Se trata de un material en línea para el cuál se están elaborando e introduciendo mapas conceptuales. En la actualidad, la teoría y problemas que se pueden encontrar en la página representan un apoyo para el aprendizaje; para el futuro se espera que todo este material en línea junto con sus mapas conceptuales represente un elemento para la investigación educativa y contribuir al conocimiento pedagógico.

4 Agradecimientos

Esta investigación fue realizada gracias al apoyo de docentes y alumnos de la Universidad Autónoma Metropolitana. Un especial agradecimiento a los alumnos quienes han participado con interés y paciencia en un conjunto de actividades durante el curso. Un especial agradecimiento también al Profesor Joseph D. Novak por sus orientaciones recibidas durante la celebración del Primer Congreso Internacional sobre Mapas Conceptuales en la Universidad de Pública de Navarra, en Pamplona, España.

5 Bibliografía

Ausubel, D. (1976). Psicologia educativa. Un punto de vista cognoscitivo. México: Trillas

Ausubel, D. P.; Novak, J.D., y Hanesian, H. (1988). Psicología de la educación. México: Trillas.

Bruner, J. (1988). Desarrollo cognitivo y educación. Madrid: Morata.

De Guzmán, M. (1996): El rincón de la pizarra, Madrid, Pirámide.

De Guzmán, M. (1999): Para pensar mejor, Madrid, Pirámide

Feuerstein, R. y Hoffman, M.B. (1995). Programa de enriquecimiento instrumental. Madrid: Bruño.

Novak, J. D. (1998). Conocimiento y aprendizaje. Madrid: Alianza.

Novak, J. D. y Gowin, D.B. (1988). Aprender a aprender. Barcelona: Martínez Roca.

Piaget, J. (1979). Tratado de Lógica y conocimiento cientifico. Epistemologia de la matemática. Buenos Aires: Paidos

Sternberg, R. J. (1986). Las capacidades humanas. Barcelona: Labor

Román, M. y Díez, E. (1988) Inteligencia y potencial de aprendizaje. Madrid: Cincel.

Vygotsky, L. S. (1979). El desarrollo de los procesos psicológicos superiores. Barcelona: Crítica.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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MAPAS CONCEPTUALES Y MODELOS DIDÁCTICOS DE PROFESORES DE QUÍMICA

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Abstract. El concepto de modelo didáctico sostenido por los docentes, representa una potente herramienta intelectual para abordar los problemas de la enseñanza en el aula, ayudándonos a establecer el necesario vínculo entre el análisis teórico y la intervención práctica. Conscientes de la importancia, que para el aprendizaje de los estudiantes, reviste el modelo didáctico sustentado por los docentes, especialmente en materias como la química, se trató de determinar con este trabajo, el perfil de los modelos didácticos que sostienen profesores de química en ejercicio en el nivel medio de la educación en la Argentina. La investigación permitió determinar que el modelo didáctico denominado alternativo es el más difundido. Los mapas conceptuales han resultado de una ayuda inestimable, al momento de utilizarlos como herramienta para representar modelos didácticos en forma rápida y comprensible.

1 Introducción

Nadie puede dudar que el concepto de modelo didáctico sostenido por los docentes, represente una potente herramienta intelectual para abordar los problemas de la enseñanza en el aula, ayudándonos a establecer el necesario vínculo entre el análisis teórico y la intervención práctica. Sin embargo, esta conexión muchas veces es ignorada en la propuesta pedagógica de los profesores, especialmente en el nivel medio, donde es común que los mismos, estén firmemente convencidos de que lo único importante a saber por el profesor es el contenido analítico de la asignatura.

Conscientes de la importancia, que para el aprendizaje de los estudiantes, reviste el modelo sustentado por los docentes, especialmente en materias como la química, se trató de determinar con este trabajo, el perfil de los modelos didácticos que sostienen profesores de química en ejercicio en el nivel medio de la educación en la Argentina.

Como principal objetivo de esta investigación, nos propusimos aprovechar la utilización de mapas conceptuales para representar los modelos didácticos más importantes, presentes en la bibliografía sobre enseñanza de las ciencias, para luego, en base a las proposiciones centrales obtenidas, elaborar una encuesta que se administró a docentes (N=43) en servicio, participantes de un curso de perfeccionamiento sobre didáctica de la química, dictado en el marco de la maestría de educación en ciencias exactas y naturales.

2 Concepciones de los profesores

La profesión docente posee la particularidad de ejercerse en un sistema complejo donde se interactúa con otras personas (alumnos, padres, colegas, etc.), con los conocimientos científicos de la disciplina que aborde y con las exigencias institucionales del sistema educativo (marco normativo, exigencias espaciales, temporales y sociales). Estas interacciones a su vez, están sesgadas por la ideología del docente y su experiencia en la práctica educativa, las que condicionan el proceso de enseñanza-aprendizaje. Estos dos últimos aspectos permiten caracterizar los diversos modelos didácticos. Es decir, que a la hora de elaborar una unidad didáctica concreta, lo que piensan los profesores determina el resultado, por eso es importante reflexionar sobre los tipos de concepciones del profesorado acerca de todo lo que se va a enseñar. La evolución de las concepciones de los profesores acerca de lo que se debe y se puede enseñar recorre un camino complejo que se ha puesto de manifiesto en distintos trabajos de las escuelas del pensamiento didáctico, ya sea de forma explícita o implícita. Como consecuencia de ellos los autores encuentran al menos cuatro tipos diferentes de profesor, o modelos didácticos que en forma muy breve analizaremos en este trabajo.

3 Los modelos didácticos

En una época en la que estamos viviendo la aplicación de reformas del sistema educativo, no sólo en Argentina, sino en muchos otros países (y especialmente en países latinoamericanos), hay algunas cuestiones que siguen siendo

claves en el ámbito de la educación universitaria, como por ejemplo: ¿Qué tipo de conocimientos teóricos y prácticos hay que proporcionar hoy a los estudiantes? ¿Qué perfil profesional requiere la sociedad actual? ¿Qué tipo de metodología habría utilizar para lograr el perfil profesional deseado? ¿Cómo motivar a los estudiantes para que se comprometan a lograr los objetivos propuestos en el diseño curricular? etc. etc. Todas éstas, y otras preguntas se pueden incluir en una cuestión más amplia e integradora: ¿qué modelo didáctico consideramos adecuado como instrumento de análisis y de intervención en el salón de clases?

El concepto de "modelo didáctico" constituye una herramienta intelectual útil, para abordar los problemas de la enseñanza en el aula, ayudándonos a establecer el necesario vínculo entre el análisis teórico y la intervención práctica; conexión que tantas veces se ignora en la propuesta pedagógica de los docentes, especialmente a nivel medio, donde es común escuchar: "lo único importante que debe saber el profesor es el contenido analítico de la asignatura". No es necesario aclarar, la gran cantidad de variables que intervienen en el proceso de enseñanza, que se ignoran con este tipo de afirmaciones, como por ejemplo, producciones teóricas de carácter pedagógico, psicológico, sociológico, curricular, materiales didácticos, las experiencias prácticas de grupos innovadores, las actuaciones concretas de profesores en sus aulas y una larga serie de etcéteras.

Por didáctica entenderemos al campo de conocimientos que se ocupa de explicar los procesos de enseñanza y aprendizaje en el ámbito áulico, con el fin de fundamentarlos para que se concreten en modelos de trabajo docente. Esta concepción ha sufrido cambios a través del tiempo; antes trataba de prescribir las condiciones ideales de enseñanza para un aprendizaje eficaz; ahora su función es la de brindar a los docentes, posibilidades de reflexión sobre su práctica, para que se puedan tomar decisiones adecuadas respecto al propio proceso de enseñanza-aprendizaje que está llevando a cabo con sus alumnos.

Si bien el trabajo docente es eminentemente práctico, detrás de esa práctica debe haber un cuerpo teórico que explique en qué fundamento se basa esa práctica. Aunque también es real que aunque toda práctica conlleva una teoría, no significa que siempre que hacemos algo lo hagamos conscientes de cuál es el encuadre teórico que lo respalda.

En la profesión docente en la que hay que intervenir socialmente con otras personas, inevitablemente se ponen de manifiesto las concepciones ideológicas personales para juzgar todo el proceso de enseñanza-aprendizaje que se realiza, aunque sea una ideología elemental y de práctica inconsciente. Esto lleva por supuesto a una pluralidad de modelos.

Cabe aclarar que la palabra "modelo" en didáctica aparece como un estereotipo de posible alternativa a la enseñanza-aprendizaje. Como cualquier otro, los modelos didácticos son una interpretación de la realidad que sólo tienen validez en un campo de aplicación determinado, pero cuya interpretación suele ser inexacta fuera de los límites de utilidad, es decir, tienen un rango de validez.

También se puede afirmar que un modelo didáctico es un esquema mediador entre la realidad y el pensamiento, una estructura en torno a la que se organiza el conocimiento y tendrá siempre un carácter provisorio y aproximativo a la realidad. Por otra parte, también se constituye en un recurso para el desarrollo técnico y la fundamentación científica de la enseñanza, con la finalidad de evitar que continúe siendo "una forma empírica y particular", alejada de cualquier formalización.

Donde mejor se refleja el pensamiento del profesor acerca de lo que es enseñar, es en su trabajo docente en el aula y con sus alumnos. "Se enseña en función de cómo se piensa". De esta manera se puede interpretar la planificación, como un proceso de reflexión-previsión-propuesta de acción del profesor con sus propias limitaciones: pensamiento del profesor, contexto de la enseñanza, realidad del aula, etc." En definitiva, la adopción de una forma de planificar significa e implica asumir un determinado modelo didáctico.

La experimentación y los problemas son actividades de razonamiento que dan valor a una ciencia escolar que se construye para conocer mejor el mundo y para actuar responsablemente sobre él.

El lenguaje escrito es una manera de acceder a un nuevo nivel epistémico, es así como se reconoce que el escribir sobre los experimentos, trabajos de laboratorios docentes, monografías etc. es una vía imprescindible para construir el conocimiento científico. De esta manera, el modelo teórico puede llegar a ser un texto, pero con

significado experimental, porque dice algo concreto sobre el mundo. En tal sentido, el lenguaje como vehículo de comunicación y de construcción escrita de significados reclama una actividad docente concebida socialmente.

Por último se hace necesario a la hora de pensar un modelo didáctico para Química, rescatar aquellos aspectos que se han analizado aquí y que caracterizan la ciencia escolar: es ciencia, es experimental, es discursiva, es autónoma y proporciona autonomía, es aplicada, es diversa y es rigurosa.

4 Algunas características de los modelos didácticos

Si bien, debido a la gran cantidad de modelos que existen, resulta extremadamente difícil tratar de caracterizar los modelos didácticos sostenidos por los docentes, se pueden realizar aproximaciones a los mismos de diversas formas.

Por ejemplo, Fernández González, J. (et. al., 1999) en su libro titulado ¿Cómo hacer unidades didácticas innovadoras? Realiza un somero repaso de algunas de las principales posiciones didácticas, para ver su efecto en la elaboración de unidades didácticas. En este caso se distinguen 5 modelos, denominados: modelo transmisor, modelo tecnológico, modelo artesano humanista, modelo del descubrimiento y modelo constructivista.

Por su parte, F. F. García Pérez (1997) a partir de fuentes diversas del Proyecto IRES, elabora una clasificación, basada en el análisis de cinco dimensiones características: para qué enseñar, qué enseñar, ideas e intereses de los alumnos, cómo enseñar y evaluación resultando así cuatro modelos didácticos, denominados: 1) tradicional, 2) tecnológico, 3) epontaneísta y 4) alternativo.

En este trabajo, para cumplir con los objetivos propuestos, los representaremos mediante el uso de mapas conceptuales, tomando como referencia los rasgos básicos elaborados por F. F. García Pérez.

De tal manera, resultan los perfiles que se muestran a continuación, donde se puede apreciar que los mapas conceptuales permiten reflejar en forma clara y concisa, los principales rasgos característicos de cada modelo identificado por F. F. García Pérez (Ibíd.)

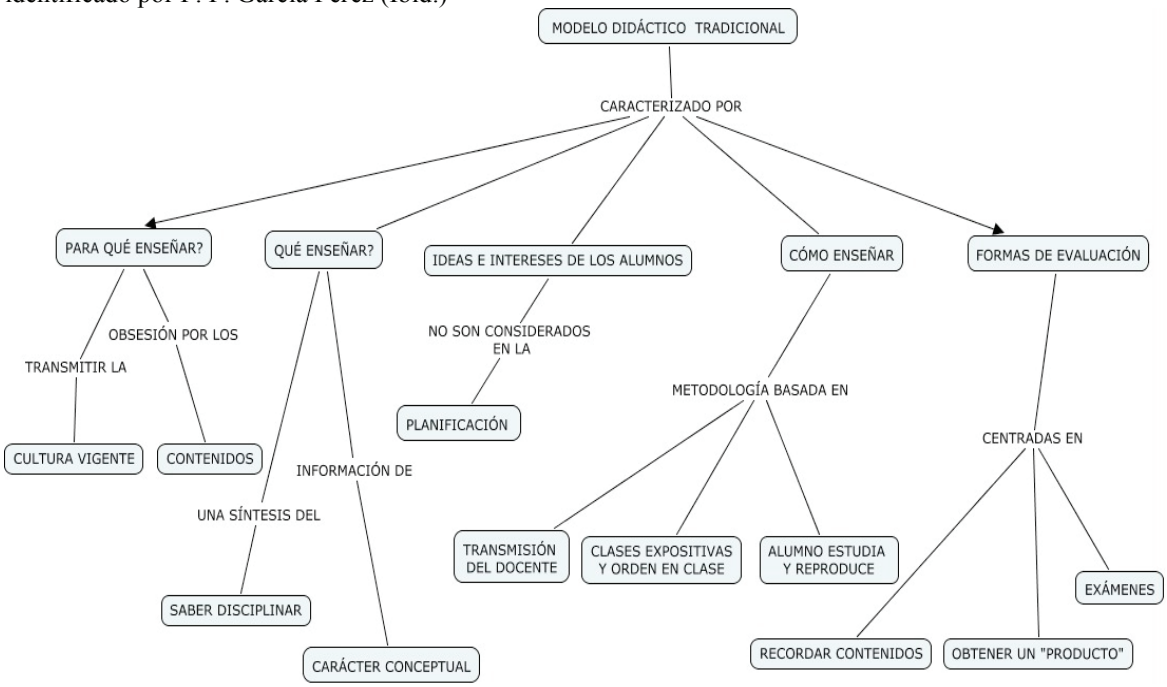


Figura. 1: Modelo tradicional

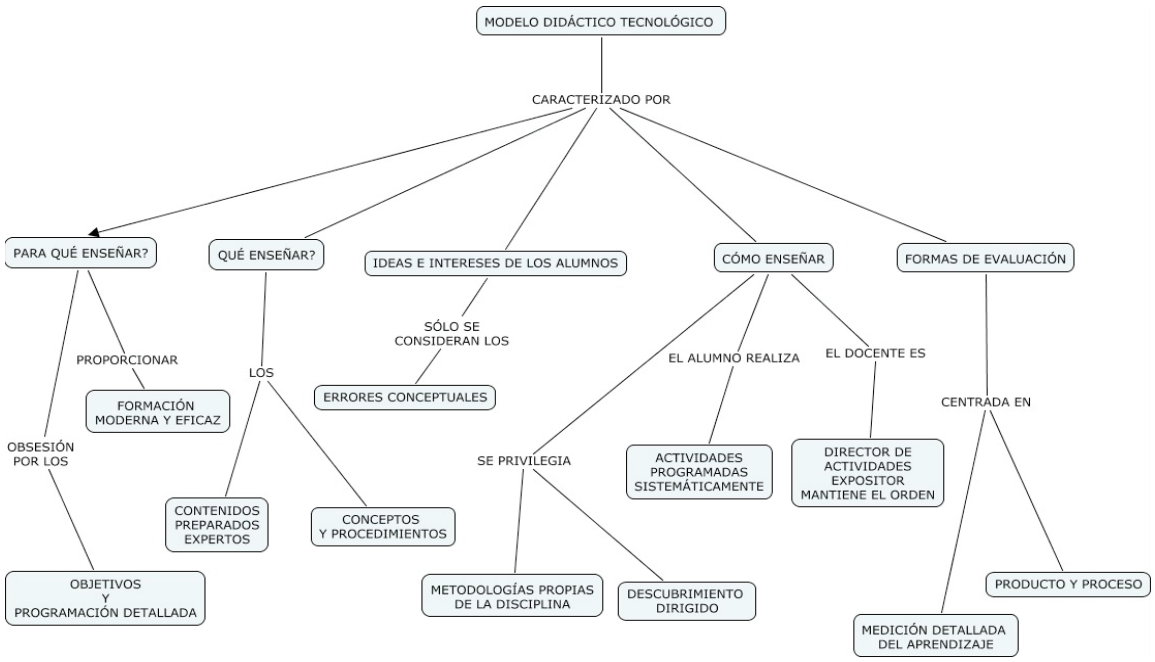


Figura 2: Modelo tecnológico

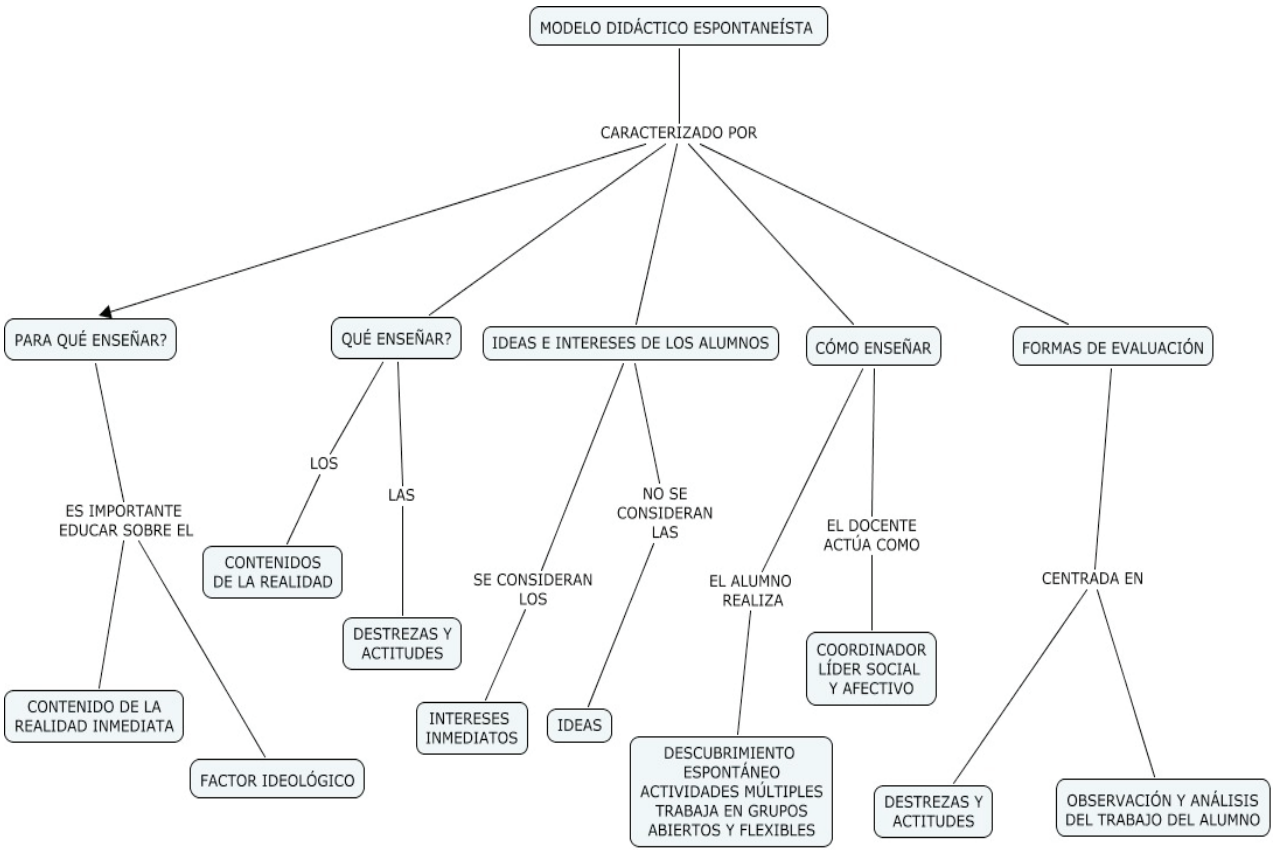


Figura 3: Modelo espontaneísta

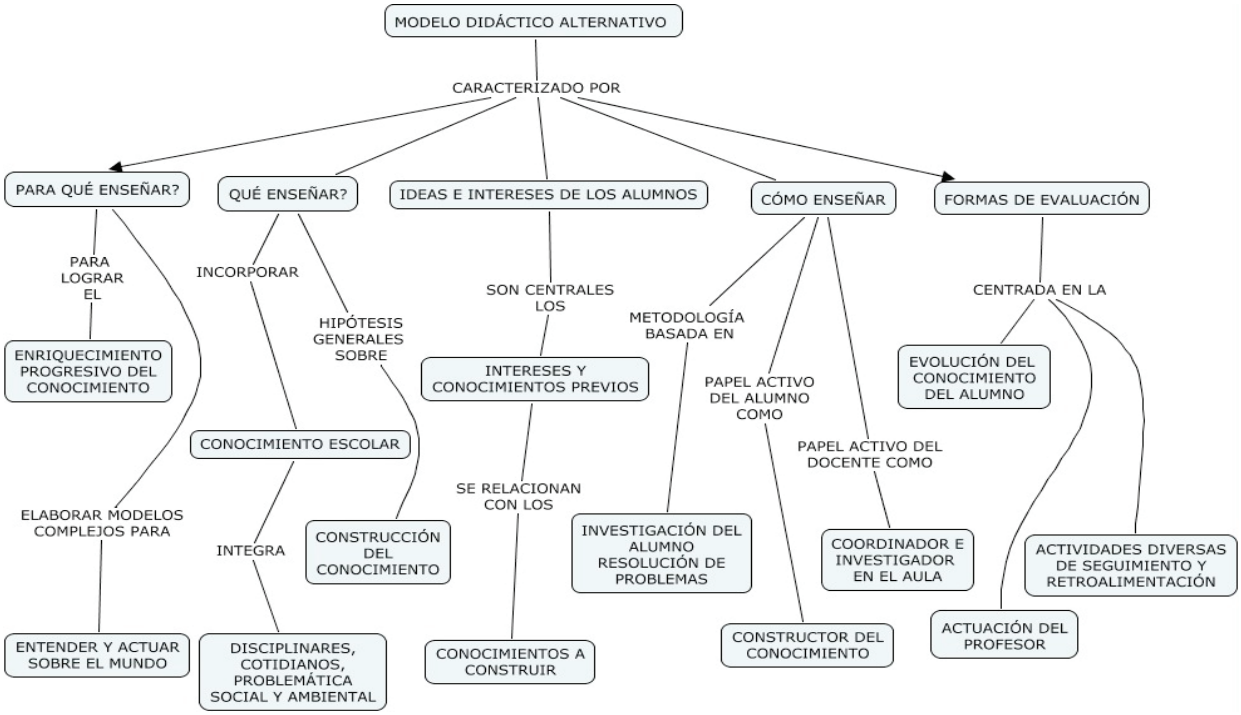


Figura 4: Modelo alternativo

5 Metodología de la investigación realizada

En base a los mapas conceptuales presentados anteriormente, fue muy sencillo elaborar la encuesta para suministrar a los docentes, la misma se puede ver en el anexo número 1.
Una vez obtenidas las respuestas de los profesores, se procedió a procesar los resultados, mediante el volcado de los resultados en planillas tipo Excel, que permitieron la representación gráfica en dos formas ilustrativas, que se muestran a continuación:

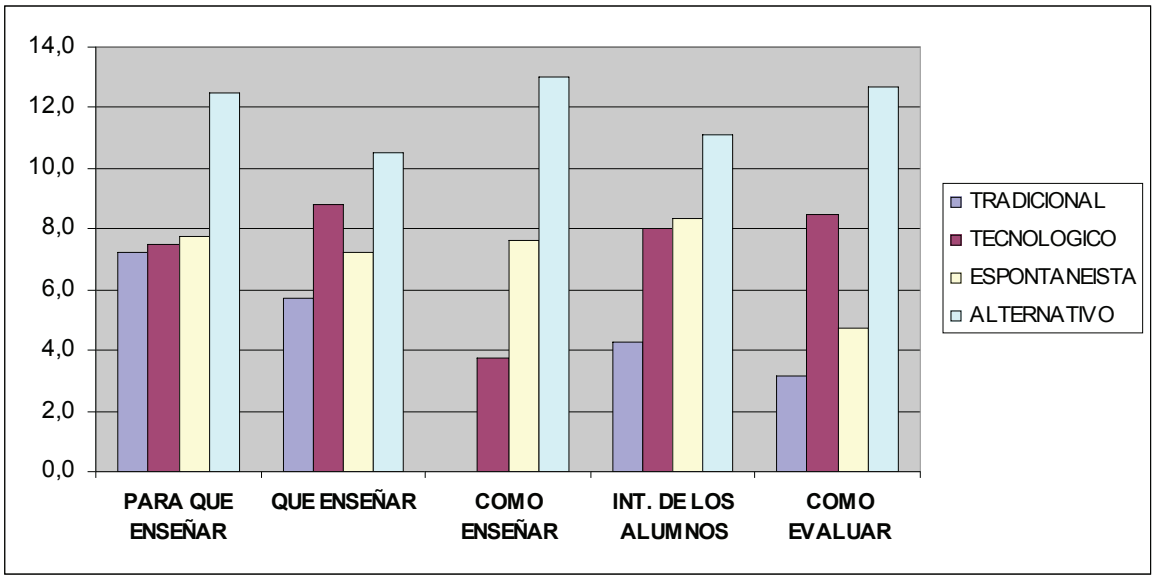


Figura 5: Gráfico de barras sobre resultados de la encuesta

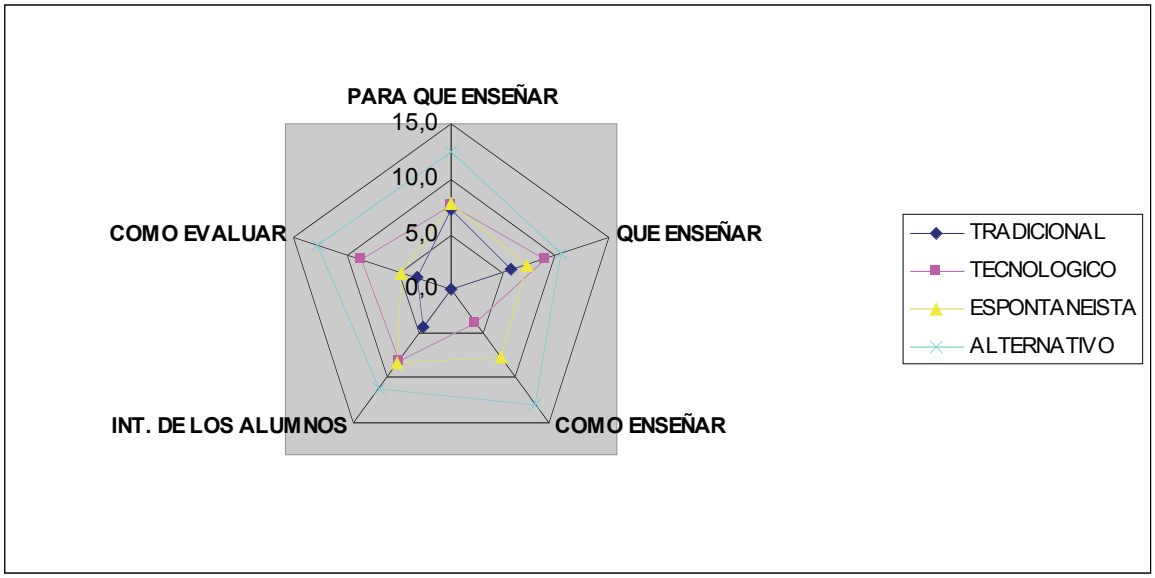


Figura 6: Gráfico pentágono sobre resultados de la encuesta

En ambos gráficos puede observarse el predominio del modelo didáctico alternativo, que por las características antes vistas coincide con un abordaje constructivista de la enseñanza. A cierta distancia del alternativo, pero con casi el mismo orden de significancia le siguen el tecnológico y el espontaneísta, siendo el cuarto lugar ocupado por el modelo tradicional.

6 Conclusiones

Si analizamos más en detalle los resultados, o sea en base a cada una de las cinco dimensiones utilizadas en la descripción de los modelos, vemos que siempre el primer lugar lo ocupa el modelo alternativo, por lo restringiremos los siguientes comentarios a los otros tres modelos.

Para qué enseñar: En esta dimensión corren bien parejo los restantes tres modelos, donde vemos, sorpresivamente la persistencia de creencias tradicionales en los profesores de química, en especial sobre la obsesión por los contenidos y la transmisión de la cultura vigente, durante las clases. Por supuesto, también son muchos los que abogan por la obsesión por los objetivos y la formación "moderna y eficaz", características del modelo tecnológico, muy difundido en las décadas del 80 y 90 del siglo pasado.

Qué enseñar: En esta dimensión vemos que predomina el modelo tecnológico, que como sabemos ponía el énfasis en los saberes de la disciplina y los contenidos preparados por expertos. Como comentario podemos acotar que luego en la práctica docente, son muy pocos los profesores que verdaderamente utilizan este tipo de contenidos en las clases, ya que por lo general se recurre a libros de texto, no siempre escritos por expertos de la disciplina y bastante tiempo después de su edición al mercado.

Otra característica a destacar en esta dimensión es el tercer lugar del modelo espontaneísta que le confiere importancia a las destrezas y actitudes, con contenidos seleccionados de la realidad inmediata.

Cómo enseñar: Lo notable de esta dimensión es la desaparición total del modelo tradicional, cosa muy auspiciosa, lo mismo que el segundo lugar ocupado por el modelo espontaneísta, basado en la metodología del descubrimiento, muy difundida, aun con diversas variantes en las últimas décadas y en la actualidad, aunque en franca desaparición, como lo demuestra la predominancia del modelo alternativo. Se debe reconocer que en este modelo también se tienen en cuenta los intereses inmediatos de los alumnos, pero no sus ideas, erróneas o no.

Ideas e intereses de los alumnos: En esta dimensión vuelven a igualarse los modelos tecnológicos y espontaneísta, por lo que debe destacarse la importancia que el tecnológico le confiere a los "errores" conceptuales de los alumnos, aunque solo para sustituirlos con otros "correctos". Por supuesto esta postura no es la que actualmente se acepta, especialmente por la necesidad de considerar también los intereses, tanto en relación con el conocimiento como en relación con la construcción de ese conocimiento.

Evaluación: En este aspecto quedan bastante relegados los modelos tradicionales y espontaneísta, a favor del tecnológico, lo que demuestra la persistencia también de las evaluaciones basadas en la "medición"de los aprendizajes efectuadas mediante distintos tipos de pruebas, conceptuadas como simples mediciones sobre contenidos específicos, aunque también se intenten medir algunos procesos.

Referencias

Ausubel, D., Novak, J.D., y Hanesian, H. "Educational Psychology, a cognitive view". 2nd Edition (Holt, Rinehart and Wiston, New York, 1978).

Apel, Jorge, 1993. Evaluar e informar en el proceso de enseñanza-aprendizaje. Aique Grupo Editor S.

Bloom, B.S. "Human characteristic and school learning" (McGraw Hill, New York, 1976)

Carroll, J. (1963) A model for school learning. Teacher College Record, 64, 723-733

Chevallard, Y. (1977). "La transposición didáctica" Buenos Aires: Aique

Chrobak, Ricardo, 1998. "Metodología para el logro de aprendizajes significativos". Ed. EDUCO. Universidad Nacional del Comahue. Neuquén, Argentina.

Chrobak, R. (1992) "Learning how to teach Introductory Physics Courses" Master's Thesis (Cornell University, Ithaca, New York)

Chrobak, R. "Análisis de las opiniones de los estudiantes sobre la Enseñanza de Cursos Introductorios de Física" Actas del Primer Congreso Nacional sobre Problemática de la Enseñanza de la Física en Carreras de Ingeniería, Instancia Final, Paraná, Entre Ríos, 1993.

Chrobak, R. "Uso de estrategias facilitadoras del aprendizaje significativo en los cursos de Física introductoria". - 1995 - Revista de Enseñanza de la Física. Editada por la Asociación de Profesores de Física de la Argentina (APFA) - Volumen 8 - Nº 1 - pp. 7-21.

Chrobak, R., Herrera, C. -1996- "Experiencia piloto para el desarrollo de un nuevo modelo instruccional" Revista Brasileira de Ensino de Física, Vol. 18, Nro 2, pp. 122-136.

Coleman, L.A., Holcomb, D.F. & Rinden, J.S. (1988). "The Introductory University Physics Project 1987-1995: What has it accomplshed? American Journal of Physics pp.124-137, febrero 1988.

Coll, César y Solé, Isabel, 1994. La interacción profesor alumno en el proceso de enseñanza aprendizaje. En Coll, César, José Palacios y A. Marchesi (comps) Desarrollo psicológico y educación II. Psicología de la Educación. Madrid. Alianza.

Fernández González, J. (1999) ¿Cómo hacer unidades didácticas innovadoras?. Diada Editora. Sevilla.

Gaido, L.G., (2003) Una propuesta de enseñanza desde el campo de la biología en la educación de adultos. Tesis de maestría, Universidad Nacional del Comahue, Neuquén, Argentina

García Díaz, J.E. y García Pérez, F.F. Aprender investigando. Una propuesta metodológica basada en la investigación. Sevilla: Díada, 1989, 5ª ed. 1999.

García Pérez, F.F. La didáctica como aplicación metodológica. Con-Ciencia Social, 1997, nº 1, p. 281-288.

Gowin, D.B. (1981) "Educating". Cornell University Press, Ithaca, New York

Hodson, D. (1994). Hacia un enfoque más crítico del trabajo de laboratorio. Revista Enseñanza de las Ciencias. 12 (3), 299-313.

ANEXO NÚMERO 1

Estimado docente: Como diagnóstico de este curso de didáctica de la química, nos interesa saber con cuales de las siguientes proposiciones está compenetrado.
Coloque una "A" al final de la proposición si acuerda con la misma, una "D" si está en desacuerdo y una "I" si está indeciso entre la dos anteriores.

¿Para qué enseñar?
Yo enseño para:

1. Proporcionar las informaciones fundamentales de la cultura vigente.
2. Cubrir los contenidos que figuran en el currículum
3. Proporcionar una formación "moderna" y "eficaz".
4. Alcanzar los objetivos del currículum, siguiendo una programación detallada.
5. Educar al alumno imbuyéndolo de la realidad inmediata.
6. Que los alumnos entiendan la importancia del factor ideológico.
7. Enriquecimiento progresivo del conocimiento del alumno hacia modelos más complejos de entender el mundo y de actuar en él.
8. Que los alumnos tomen conciencia de la importancia de la opción educativa que adopten.

¿Qué enseñar?

1. Una síntesis del saber disciplinar.
2. Un programa donde predominen de las "informaciones" de carácter conceptual.
3. Saberes disciplinares actualizados, con incorporación de algunos conocimientos no disciplinares.
4. Contenidos preparados por expertos para ser utilizados por los profesores.
5. Todo lo conceptual, pero otorgando también cierta relevancia a las destrezas.
6. Todos los contenidos presentes en la realidad inmediata.
7. Resaltar la importancia de las destrezas y las actitudes.
8. Conocimiento "escolar", que integra diversos referentes (disciplinares, cotidianos, problemática social y ambiental, conocimiento metadisciplinar).
9. Aproximación al conocimiento a través de una "hipótesis general de progresión en la construcción del conocimiento".

¿Ideas e intereses de los alumnos?

1. No tener en cuenta ni los intereses ni las ideas de los alumnos.
2. No tener en cuenta los intereses de los alumnos.
3. Tener en cuenta las ideas de los alumnos, considerándolas como "errores" que hay que sustituir por los conocimientos adecuados.
4. Tener en cuenta los intereses inmediatos de los alumnos.
5. No tener en cuenta las ideas de los alumnos.
6. Tener en cuenta los intereses y las ideas de los alumnos, tanto en relación con el conocimiento propuesto como en relación con la construcción de ese conocimiento.

¿Cómo enseñar?

1. Metodología basada en la transmisión del profesor.
2. Actividades centradas en la exposición del profesor, con apoyo en el libro de texto y ejercicios de repaso.
3. El papel del alumno consiste en escuchar atentamente, "estudiar" y reproducir en los exámenes los contenidos transmitidos.
4. El papel del profesor consiste en explicar los temas y mantener el orden en la clase.
5. Utilizar una metodología vinculada a los métodos de las disciplinas.
6. Actividades que combinan la exposición y las prácticas, frecuentemente en forma de secuencia de descubrimiento dirigido (y en ocasiones de descubrimiento espontáneo).
7. El papel del alumno consiste en la realización sistemática de las actividades programadas.
8. El papel del profesor consiste en la exposición y en la dirección de las actividades de clase, además del mantenimiento del orden.
9. Metodología basada en el "descubrimiento espontáneo" por parte del alumno.
10. Realización por parte del alumno de múltiples actividades (frecuentemente en grupos) de carácter abierto y flexible.
11. Papel central y protagonista del alumno (que realiza gran diversidad de actividades).
12. El papel del profesor es no directivo; coordina la dinámica general de la clase como líder social y afectivo.
13. Metodología basada en la idea de "investigación (escolar) del alumno".
14. Trabajo en torno a "problemas", con secuencia de actividades relativas al tratamiento de esos problemas.
15. Papel activo del alumno como constructor (y reconstructor) de su conocimiento.
16. Papel activo del profesor como coordinador de los procesos y como "investigador en el aula".

¿Cómo es la evaluación?

1. Centrada en "recordar" los contenidos transmitidos.
2. Atiende, sobre todo al producto.
3. Realizada mediante exámenes.
4. Centrada en la medición detallada de los aprendizajes.
5. Atiende al producto, pero se intenta medir algunos procesos
6. Realizada mediante tests y ejercicios específicos.
7. Centrada en las destrezas y, en parte, en las actitudes.
8. Atiende al proceso, aunque no de forma sistemática.
9. Realizada mediante la observación y el análisis de trabajos de alumnos
10. Centrada, a la vez, en el seguimiento de la evolución del conocimiento de los alumnos y de la actuación del profesor
11. Reformulación a partir de las conclusiones que se van obteniendo.
12. Realizada mediante diversidad de instrumentos de seguimiento

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

MAPAS CONCEPTUALES Y PRESENTACIÓN GRÁFICA DEL TESAURO: APLICACIÓN A LAS BIBLIOTECAS EDUCATIVAS

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Abstract. Tesauros y mapas conceptuales constituyen sistemas de representación del conocimiento procedentes de diferentes disciplinas pero con características semejantes que, aunadas, pueden ser útiles para la representación de conocimiento y organización de contenidos en Educación. Desde esta perspectiva se analiza la posibilidad de aplicación de mapas conceptuales a la presentación gráfica de los tesauros, apoyándose en la circunstancia de que ambos instrumentos convergen en la biblioteca educativa. La incorporación de los mapas conceptuales al diseño de información de la nueva biblioteca educativa, en su doble dimensión CRA (Centros de Recursos para el Aprendizaje) y CRAI (Centros de Recursos para el Aprendizaje y la Investigación) promueven un sistema propio de organización y gestión de los contenidos de *su colección*, pero además le permite acometer con eficacia el reto de convertirse en el *centro de recursos* que garantice la *educación en competencias* y la formación continuada, no sólo por consumo de información, sino por ejercicio de estrategias y modelos de competencias que contemplan las normas internacionales para la Alfabetización en Información.

1 Introducción

Como consecuencia del impacto producido por la difusión e incorporación de las Tecnologías de la Información y Comunicación (TIC), las políticas educativas de la Unión Europea (UE) están, dando un apoyo a la **e-educación** (*e-education*) que se ha visto incrementado de forma exponencial en el desarrollo programático de las actuaciones encaminadas a impulsar la Sociedad de la Información.

Estas políticas educativas de la Unión Europea están impulsando un nuevo modelo educativo que se sustenta en la adquisición de competencias, opuesto al actualmente imperante: una capacitación centrada en un conjunto cerrado de conocimientos y en el dominio de destrezas y habilidades. En este nuevo modelo educativo, basado en las teorías del aprendizaje significativo, en el "aprender a aprender", el elemento activo y central del aprendizaje es el alumno. Además, debe desarrollarse en un espacio distinto al tradicional, un espacio educativo que trasciende el espacio del aula extendiéndose en el espacio digital, en entornos colaborativos, dinámicos y asíncronos. Para que este aprendizaje sea eficaz, los recursos digitales deben ser estructurados, representados y organizados de acuerdo con sus potencialidades educativas.

Éstas últimas, la representación y organización de recursos principalmente, han sido el quehacer primordial de los profesionales de la Documentación (*Information Science*) desde sus inicios. No es de extrañar, por tanto, que la adaptación de la educación universitaria a este modelo educativo, a través del Espacio Europeo de Enseñanza Superior, surgido a partir de la Declaración de Bolonia, esté impulsando a su vez la transformación de las bibliotecas universitarias en Centros de Recursos para el Aprendizaje y la Investigación (CRAI)[1]. Las bibliotecas de los centros educativos o bibliotecas educativas, pasan a tener un papel fundamental en el apoyo al proceso de aprendizaje del alumno, al pivotar la función del profesor de fuente del saber a tutor y guía, pues ellas son las depositarias de los recursos educativos que el alumno va a necesitar para elaborar su conocimiento.

Uno de los de los instrumentos de las Ciencias de la Documentación que ha mostrado una mayor versatilidad en la representación y recuperación del contenido documental es el tesauro. Es, así mismo, el más adecuado para el espacio digital, por su capacidad asociativa y relacional. Al igual que los mapas conceptuales han dado un salto de adaptación a la Web, en la que se están aplicando con éxito como formas de estructuración conceptual. Nuestra contribución se centra en la exploración del interés que puede tener la utilización de los mapas conceptuales para hacer explícito el conocimiento experto que el tesauro encierra, ayudando a las bibliotecas, para las que el tesauro es un instrumento de trabajo, a realizar el papel activo de apoyo al aprendizaje que se les está demandando.

[1] REBIUN, organismo que aglutina a las bibliotecas universitarias españolas, está impulsando la investigación y la transformación de éstas en CRAI, con el fin de proporcionar el apoyo adecuado al nuevo modelo educativo universitario europeo.

2 Uso de mapas conceptuales en la presentación gráfica del tesauro

Tesauros y mapas conceptuales constituyen sistemas de representación del conocimiento (*KOS*) que, aunque proceden de diferentes disciplinas, poseen características semejantes. Esta semejanza permite la utilización conjunta de ambos sistemas, de forma que la unión de las potencialidades de cada uno de ellos pueda ser útil para representación de conocimiento y organización de contenidos en Educación.

2.1 Tesauros

Los tesauros, en su concepción actual, comenzaron a desarrollarse en los años 50 como respuesta a la ineficacia demostrada por las palabras-clave no controladas y otros vocabularios controlados, cuando eran utilizados en la recuperación de información, cuya capacidad para representar y recuperar el contenido documental resultaba insuficiente ante una información exponencialmente creciente. Su función es proporcionar un vocabulario normalizado que de consistencia a la indización y facilite la búsqueda en los sistemas de recuperación de la información. Esto implica un doble uso que hace de puente entre la colección documental, el profesional y el usuario de la información al facilitar la coincidencia entre lenguajes (Lancaster, 2002). Además de en la descripción por indización y en la recuperación, los tesauros pueden ser utilizados en las técnicas de búsqueda en sistemas automatizados, con la intención de refinar o expandir la capacidad del sistema. Así mismo, pueden ser utilizados como instrumentos de navegación y ayuda, al proporcionar definiciones de los términos y otras aplicaciones menos habituales (Aitchison, J., Gilchrist, A. y Bawden, D., 1997)

La estructura de los tesauros está dirigida por dos estándares internacionales que actúan como recomendaciones: la norma ISO 2788:1986 (International Organization for Standardization, 1986), cuya primera edición data del año 1974, dedicada a los tesauros monolingües. y la norma ISO 5964:1985 (International Organization for Standardization, 1985) centrada en los tesauros multilingües. Estas normas recogen tres relaciones básicas, todas ellas recíprocas, entre los términos de un tesauro: de equivalencia, jerárquicas y asociativas. Así mismo, recogen tres tipos de presentación: alfabética, sistemática y gráfica. Aunque la alfabética es obligada, suele ir acompañada de una o las dos formas complementarias para presentar un panorama completo de su organización (Lancaster, 2002). La presentación gráfica debe mostrar, de preferencia, las relaciones jerárquicas existentes entre descriptores dejando la indicación de los términos asociados a los márgenes del gráfico. Sus formas más usuales de representación son los diagramas de estructura arborescente, los diagramas de flechas y los terminogramas.

La automatización y el desarrollo de la Web han ido evidenciando, por un lado, la adaptación de los tesauros a nuevos usos, integrándose, en conjunción con el lenguaje natural, en los Sistemas de Gestión de la Información (SGD) y en los sistemas de búsqueda en la red y, por otro, sus posibilidades hipertextuales a través de las relaciones para servir como elementos de navegación. Sin embargo, su presentación gráfica queda relegada a un plano meramente ilustrativo, cuando no inexistente. Uno de los escasos ejemplos disponibles es el del *Human Emotions Thesaurus* (http://www.slais.ubc.ca/courses/libr512/04-05-wt2/thesauri/HET/graphical_display.htm) o el *Smart Suit Thesaurus,* de tipo arborescente (http://www.slais.ubc.ca/courses/libr512/03-04-wt2/thesauri-student/smart_suits/L-512Thesaurus/graphical.htm,). En el entorno comercial, una de las tecnologías que permiten la visualización de tesauros de mayor éxito está siendo ThinkMap, que soporta el desarrollo realizado para Visual Thesaurus (http://www.visualthesaurus.com).

2.2 Tesauros y Mapas conceptuales

Al igual que en el caso de los tesauros, la automatización primero y la Web después han llevado a los mapas conceptuales al medio digital, derivando de su realización manual a la automatizada mediante programas específicos (CmapTools y DigiDocMap, entre otros). Estos aportan ventajas para su construcción y mantenimiento, mejoran su apariencia visual y facilitan el movimiento a través de mapas complejos o grandes. Paulatinamente han ido incorporando funcionalidades hipertextuales que permiten integrar, a modo de ilustración de los conceptos, todo tipo de recursos digitales a través de enlaces, convirtiéndolos en entornos interactivos. Este desarrollo ha abierto nuevas perspectivas para su utilización, entre las que se incluyen el desarrollo conceptual de sistemas hipertextuales, estructuras de navegación, indización y sistemas de recuperación de información, así como modelos de conocimiento (Lin & Hsueh, 2006).

En la literatura han aparecido, a lo largo del tiempo, diversas aunque escasas referencias a la utilización conjunta de ambos instrumentos (Duncan, 1987; Sherrat & Schlabach, 1990; Saadani & Bertrand-Gastaldy, 2000). Uno de los estudios más extensos analiza la posibilidad de transformación del vocabulario (no exactamente un tesauro según la norma ISO) utilizado en el sistema ERIC, una extensa base de datos de documentación educativa, en mapas conceptuales de uso en Web para la mejora de su sistema de navegación (Milam, Santo & Heaton, 2001). Su conclusión fue, ya entonces, que la tecnología para llevarlo a cabo estaba disponible.

Otra de estas referencias se refiere a la utilización de mapas conceptuales en la construcción de tesauros. (Naumís Peña, 2001). Precisamente, el tesauro que hemos escogido para ilustrar el presente trabajo se construyó utilizando esta técnica, si bien en su versión electrónica ([2] no se han incluido los mapas correspondientes.

2.3 Aplicación de mapas conceptuales a la presentación gráfica del tesauro

Como ilustración del uso y las ventajas de la utilización de los mapas conceptuales para mostrar el conocimiento incluido en el tesauro, presentándolo gráficamente en Web, hemos utilizado el siguiente tramo, correspondiente a Ciencias Naturales, del Macrotesauro Mexicano para Contenidos Educativos.

BIOLOGÍA CELULAR
- CÉLULA
  - CICLO CELULAR
    - DIVISIÓN CELULAR
      - MEIOSIS
      - MITOSIS
        - ANAFASE
        - METAFASE
        - PROFASE
        - TELOFASE
    - INTERFASE
      - FASE G1
      - FASE G2
      - FASE S
  - COMPONENTE CELULAR
    - CITOPLASMA
      - ORGANITO SUBCELULAR
        Usado por: Organelo celular,
        - ORGANELO MEMBRANOSO
          - APARATO DE GOLGI
          - CLOROPLASTO
          - LISOSOMA
          - MITOCONDRIA
          - PEROXISOMA
          - RETÍCULO ENDOPLÁSMICO LISO
          - RETÍCULO ENDOPLÁSMICO RUGOSO
          - VACUOLA
        - ORGANELO NO MEMBRANOSO
          - CENTRIOLO
          - CILIO
          - CITOESQUELETO
          - FLAGELO
          - MICROVELLOSIDAD
          - RIBOSOMA
    - MEMBRANA CELULAR
    - NÚCLEO
      - CROMATINA
      - MEMBRANA NUCLEAR
      - NUCLEOLO
      - NUCLEOPLASMA
    - PARED CELULAR

[2] Macrotesauro Mexicano para Contenidos Educativos. Disponible en: <http://cuib.unam.mx/~tesauro> [Consultado: 17/2/2006].

CÉLULA EUCARIONTE
CÉLULA PROCARIONTE

Para su trasformación en mapa conceptual se ha utilizado la herramienta *CmapTools* (Cañas et al., 2004,) http://cmap.ihmc.us/), desarrollada por el *Institute for Human and Machine Cognition* (IHMC). Esta adaptación, únicamente de su estructura jerárquica, puede apreciarse en la Figura 1.

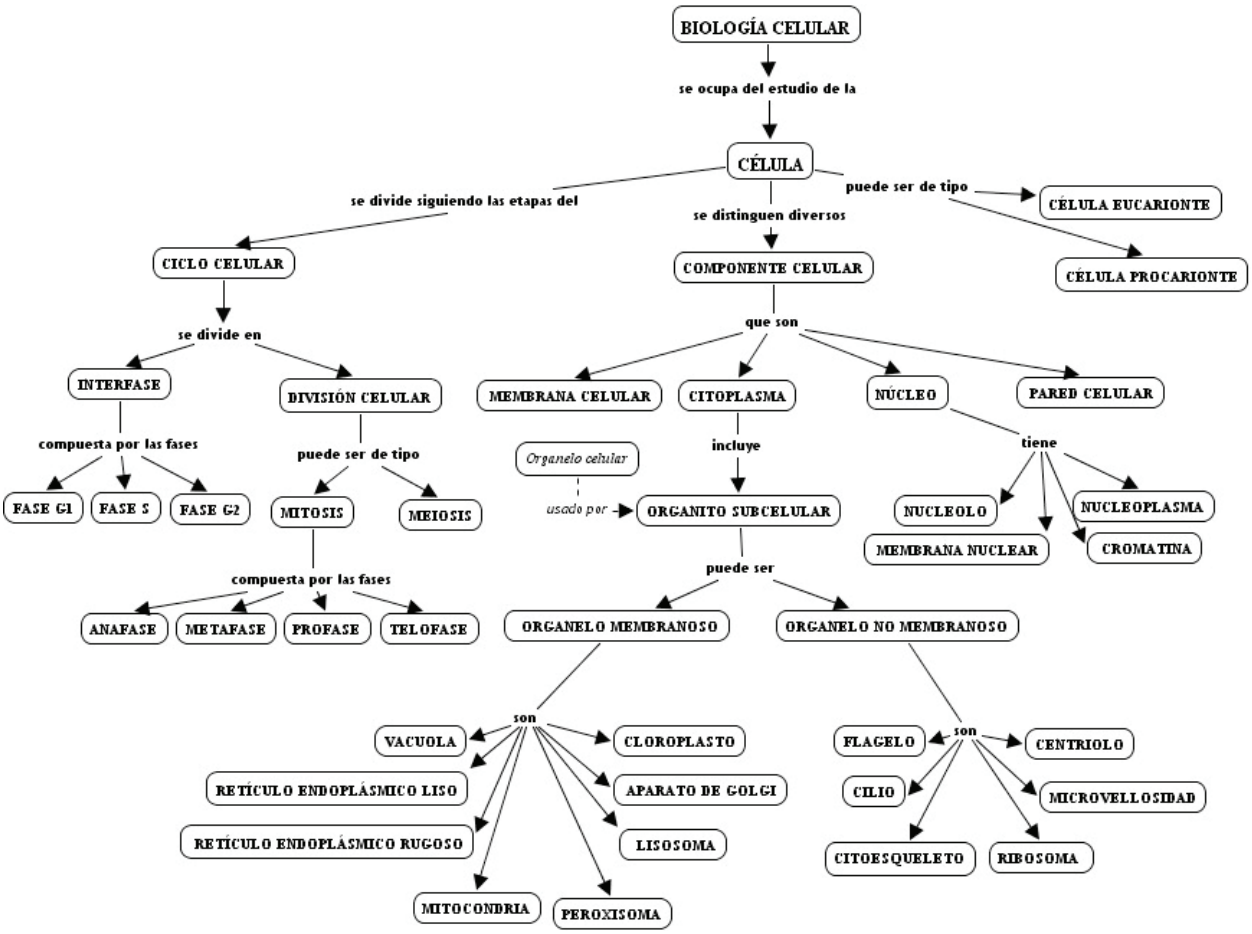


Figura Error! Unknown switch argument.. Mapa construido utilizando únicamente las relaciones jerárquicas (término genérico-término específico).

En la Figura 2 se muestra el mismo mapa, pero incorporando ya las relaciones asociativas. Unas se dan entre términos del mismo mapa (indicadas con flechas rojas) y otras con términos de mapas similares, viniendo indicado por el símbolo de enlace a otros mapas conceptuales. Igualmente, se puede enlazar con una búsqueda en el catálogo de la biblioteca por el término de indización del tesauro elegido y representado en el mapa (indicado con el símbolo "?").

Combinando las características de la herramienta CmapTool, distintas tipografías y colores, pueden ponerse de relieve las relaciones tesaurales típicas, aprovechando todas las ventajas de ambos en la biblioteca o en la web. relaciones del tesauro.

En la Figura 3 se puede observar el cómo queda señalado y enlazado el término genérico del término BIOLOGÍA CELULAR al incorporar la descripción del término BIOLOGÍA en letras mayúsculas, quedando reservadas las minúsculas para los términos asociados.

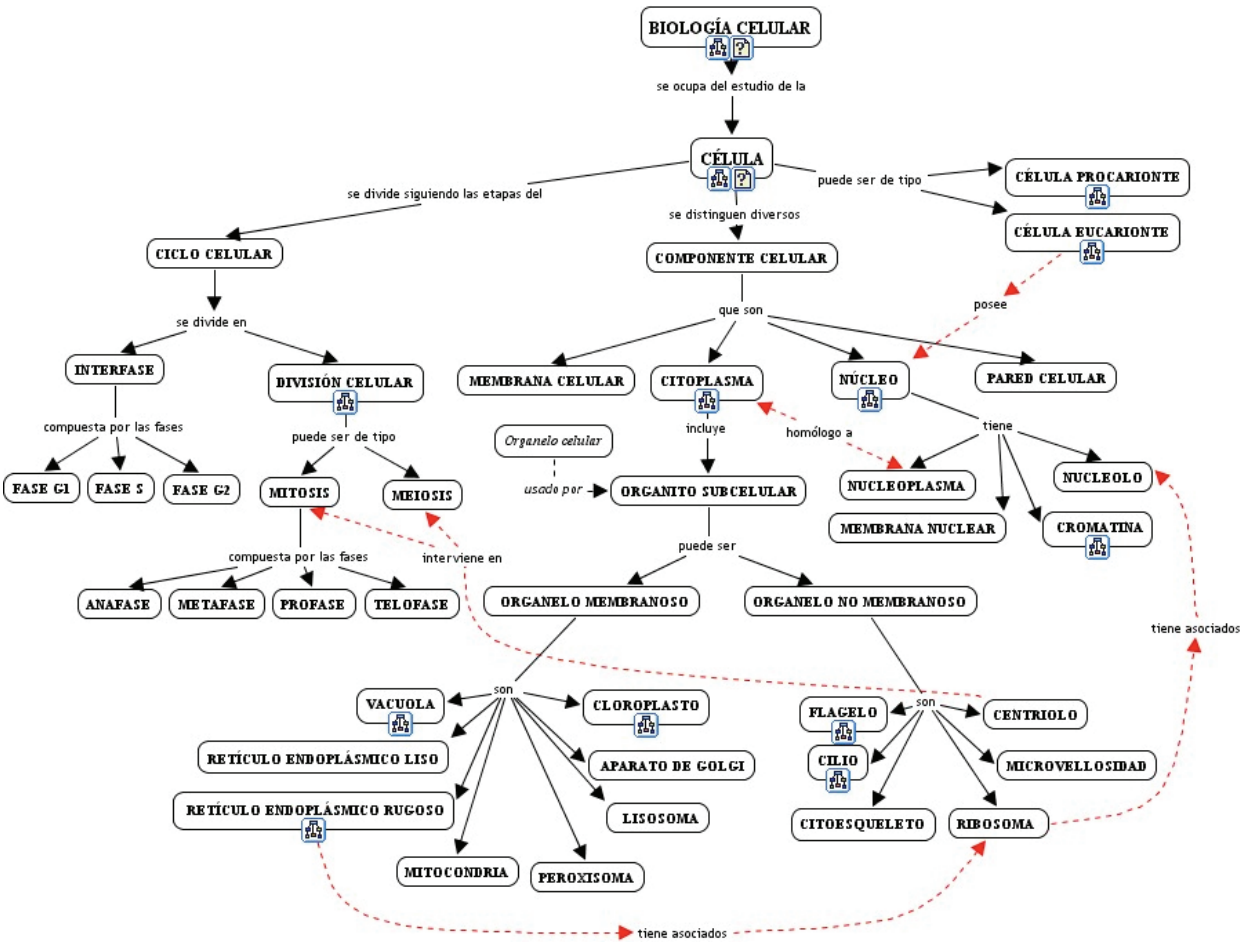


Figura 2. Mapa mostrando todas las relaciones del tesauro (jerárquicas, asociativas y equivalencia).

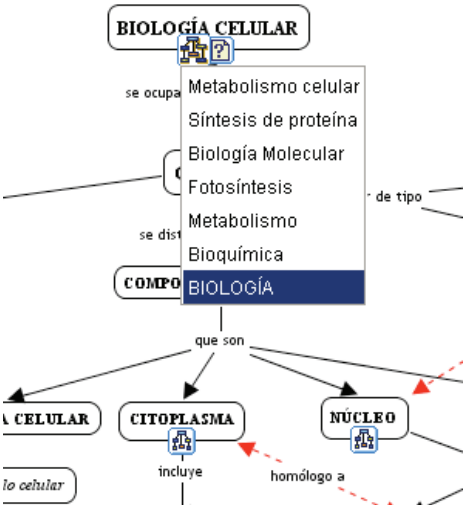


Figura 3. Detalle del mapa mostrando el enlace del término con otras áreas del tesauro.

3 Aplicación en Bibliotecas educativas

Denominamos *bibliotecas educativas* a aquellas unidades de información integrantes de una institución educativa, implicadas en el desarrollo de un proceso de enseñanza-aprendizaje de calidad. Este tipo de bibliotecas están experimentando una profunda transformación, impulsada por la emergencia de un modelo educativo adecuado a la Sociedad del Conocimiento, que las llevará desde la posición periférica que ocupan en el actual modelo educativo a otra nodal y central. Esté cambio dará lugar al CRAI (Centro de Recursos para el Aprendizaje y la Investigación) en las universidades y al CRA (Centro de Recursos para el Aprendizaje) en los centros de enseñanza primaria y secundaria, que no vienen a sustituir, sino a incorporar entre otras funciones y servicios, la biblioteca universitaria y la escolar.

Esta transformación no implica una alteración de la función primordial de las bibliotecas, en tanto que sistemas de información educativa: organizar la colección, identificando los elementos singulares de los documentos para la recuperación, y organizar y gestionar los contenidos representando los tópicos documentales, para garantizar su almacenamiento significativo y disposición para su uso. Para realizar esta función primaria el Análisis Documental, tanto de Forma como de Contenido, proporciona instrumentos que continúan siendo muy útiles, particularmente los tesauros, desde el Análisis de Contenido, por su fuerza clasificatoria, taxonómica, sindética en la formalización de relaciones, entrópica por la semántica de su estructura organizativa y específica por ser un lenguaje documental de especialidad.

Los tesauros pueden ver su función claramente reforzada si efectúan un cambio en su diseño con apoyo de los mapas conceptuales, tal como se ha indicado. Este cambio, que afecta también a otros elementos de su estructura conceptual, es muy evidente para su impacto educativo en el entorno de los CRAI y CRA, si se tienen en cuenta los desafíos a los que estas bibliotecas deben hacer frente en el contexto actual:

1. **Nuevos servicios** a una comunidad educativa que formará grupos diferenciados por el *interés*, el cual *motiva* a cada usuario en el uso del sistema de información, buscando una *biblioteca individualizada*. El sistema debe prepararse para anticipar y predecir el uso de la colección documental por sus usuarios, que acudirán al CRAI y CRA no sólo para "consumir" contenidos, sino también producirlos y editarlos (Balagué Mola, 2003). REBIUN reconoce específicamente los siguientes objetivos del servicio de los CRAI: poner a disposición de los alumnos un entorno de aprendizaje global, permitiendo que profesores y alumnos puedan trabajar de manera continuada; facilitar a la comunidad universitaria el acceso a todos los servicios y unidades que estén relacionados con el proceso del aprendizaje; estimular el aprendizaje continuo, el estudio, la lectura y la sociabilidad de la comunidad universitaria; programar en él tanto actividades curriculares como extracurriculares: actividades culturales y actividades de ocio (Martínez & Martí, 2003). Desde la perspectiva de estos nuevos servicios los mapas conceptuales proveen un medio muy adecuado por sus diversas potencialidades: es un instrumento muy amigable para "editar" la propia producción científica y los propios materiales didácticos por parte del profesor, integrando semántica y significativamente los recursos de la colección, como también es un instrumento eficaz del docente para que sus alumnos "ilustren" de forma taxonómica y estructura clasificada los conceptos constitutivos de una *unidad de conocimiento*. Los mapas conceptuales, además, se comportan como un mecanismo idóneo de control de vocabulario para acomodar el lenguaje del "creador" del mapa, con el reflejado en el corpus documental.

2. **Nuevos modelos educativos**, para fundamentar el modelo educativo de la Sociedad del Conocimiento, que se asienta sobre dos teorías pedagógicas: el *Cognitivismo* (derivación del paradigma conductista), que concibe el aprendizaje como producto de la interacción del sujeto con la información procedente del entorno, y el *Constructivismo*, para el que el conocimiento no se descubre, sino se construye a través de un proceso de aprendizaje, que utiliza conocimientos anteriores. Los principios del modelo educativo que ambas teorías sustentan promueven un proceso de aprendizaje donde la implicación del educando sea muy fuerte a través de estrategias concretas (Sancho, 2000). Los mapas conceptuales, evidentemente, según los concibió D. Novak, inspirado en las teorías de Ausubel, son una magnífica plataforma convergente del Cognitivismo y el Constructivismo: una representación mental de conocimiento, capaz de generar una estructura apta para construir un conocimiento inferido, a partir del diseño del propio mapa conceptual. Su uso efectivo en este modelo educativo que se pretende en el Espacio Europeo de Educación Superior (EEES) requiere, no sólo una plataforma tecnológica de almacenamiento e interoperabilidad de los contenidos representados en los mapas conceptuales, sino su conversión en los documentos cooperativos que sustentan una comunidad virtual; deben

ser, también, el eje de los sucesivos "tópicos" que suscitan comunidades virtuales transversales, de modo que puedan integrar *objetos de aprendizaje*, gestionados por el CRAI, cuya propiedad básica es su "reutilización"; deben ser, además, un instrumento útil para que los bibliotecarios del CRAI, presenten, editen y usen sus potencialidades para soportar los *objetos de aprendizaje* propios, destinados a capacitar en competencias y habilidades en el marco de la *alfabetización en información*, conforme a los requerimientos del Suplemento de Título, contemplado en el EEES.

3. **Nuevos recursos**, gestionados al tiempo que la colección digital y en papel, propia de las bibliotecas. El CRAI no se enfrenta a documentos con características derivadas del soporte, mensaje, formato u otra de las divisiones conocidas. El CRAI se enfrenta no a documentos con características derivadas del soporte, mensaje, formato u otra de las divisiones conocidas, que definen la *biblioteca híbrida.* La colección son "recursos", por lo que los documentos se incorporan a la colección por su *función*. Se contemplan distintas funciones, como parte de la universidad en tanto que institución polivalente, pero no cabe duda que una "función" primordial es la educativa. A los recursos informativos digitales se les confiere una vocación didáctica, y así se implementan con un diseño instructivo, tanto para su consumo como para su edición por toda la comunidad universitaria, en los denominados *objetos de aprendizaje*. Estos recursos necesitan, por definición, un procesamiento y tratamiento documental propio y diferenciado, respecto a la colección disponible en la biblioteca universitaria: los mapas conceptuales superan su posible función a una implementación de los OPACs. Las potencialidades tecnológicas de los mapas conceptuales les transforman en un instrumento adecuado para el Análisis Formal y de Contenido de los *objetos de aprendizaje*, al registrarlos y procesarlos desde la óptica de su función, su susceptibilidad de uso según el contexto del "dominio" y sus distintos enlaces hipertextuales y conceptuales, de mapa a mapa conceptual. La posibilidad de que los mapas conceptuales puedan ser interoperables por conversión a distintos lenguajes de marcado, les concede una granularidad importante en su tratamiento.

La conciencia de estos desafíos unida al reconocimiento de los posibles auxilios de los mapas conceptuales en tanto que herramienta de Análisis de Contenido, hace que en su aplicación a los CRAI fomenten dos tendencias básicas promovidas por los cambios descritos:

1. El incremento y potenciación de las **relaciones asociativas,** dirigido a configurar un buen sistema de navegación en los documentos digitales educativos, que proporcione una adecuada estructuración de la información dado que los usuarios los que captan son las relaciones conceptuales subyacentes a la estructura de la información, construyendo representaciones mentales de su contenido (Schawn, Jones & Elgin, 2002). La navegación se basa en conceptos acomodados a las asociaciones semánticas horizontales, con la flexibilidad suficiente para responder a las demandas con rapidez y eficacia adecuadas, de forma que primen las competencias del usuario en cuanto a la selección y evaluación de los recursos pertinentes para sus necesidades informativas (Fernández-Molina & Guimarães, 2002). Los tesauros están intentando evolucionar también en este sentido. A diferencia de éstos los mapas conceptuales no realizan ningún control del vocabulario, ni se configuran mediante reglas de normalización o normas para realizar las asociaciones (Moreiro González, J. A. *et al.*, 2002). El producto resulta de la visión que posea el autor del mapa, pues de él únicamente depende la elección de conceptos y de los enlaces, lo que proporciona una ventaja añadida: el diseño estructural de los mapas conceptuales hace que las asociaciones estén "disciplinadas", esto es, no existen reglas, salvo las que el autor, alumno o docente, otorguen a su mapa: el mapa conceptual flexibiliza al tesauro, pero acorde con unas "reglas" inspiradas en un diseño instructivo.

2. El desarrollo del campo de **visualización de información.** La información "ilustrada" se incorpora mediante dibujos, esquemas, gráficos, proporcionando un complemento significativo por analogía o alternativa comprensiva. Los mapas conceptuales, en este sentido, se comportan como un sistema gráfico de datos que expresan visualmente conceptos, sobre los que pueden realizarse operaciones metacognitivas de profundización. Un CRAI puede servirse de los mapas conceptuales para articular un Interfaz Gráfico de Usuario como intermediario entre las estructuras conceptuales de la información y su infraestructura semiótica, por los atributos icónicos propios de estos mapas. La visualización del Sistema de Información mediante mapas conceptuales en el CRAI reclama su espacio propio en estas unidades de información de carácter educativo, proporcionando unas prestaciones gráficas más disciplinadas que otro tipo de sistemas.

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Referencias

Aitchison, J., Gilchrist, A. y Bawden, D. (1997). Thesaurus construction and use: a practical manual. 3ª ed. Londres: Aslib.

Balagué Mola, N. (2003) La biblioteca universitaria, centro de recursos para el aprendizaje y la investigación: una aproximación al estado de la cuestión en España. En: Los Centros de Recursos del Aprendizaje y la Investigación en los procesos de innovación docente: Jornadas Rebiun 2003. Disponible en: http:biblioteca.uam.es/paginas/palma.html [Consultado el 05/04/06]

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Duncan, E. B. A concept-map thesaurus as a knowledge-based hypertext interface to a bibliographic database. In Proceeding of the 11th International Online Information Meeting, 1987, 43-52.

Fernández-Molina, J. C. & Guimarães, J. A. C. (2002). Ethical Aspects of Knowledge Organization and Representation in the Digital Environment: Their Articulation in Professional Codes of Ethics. En: López-Huertas, M. J. (ed.). Challenges in knowledge representation and Organization for the 21st century. Integration of knowledge across boundaries: proceedings of the seventh international ISKO conference, Granada (España) 10-13 Julio 2002. Alemania: Ergon. (Advances in Knowledge Organization, 8). pp. 487-499.

International Organization for Standardization (1986) Documentation: Guidelines for the establishment and development of monolingual thesauri. ISO 2788. 2ª ed. Geneva: ISO.

International Organization for Standardization (1985) Documentation: Guidelines for the establishment and development of multilingual thesauri. ISO 5964. 1ª ed. Geneva: ISO.

Lancaster, F. W. (2002). El control del vocabulario en la recuperación de información. 2ª ed. Valencia: Universidad de Valencia. (Educació. Materials, 12).

Lin, F. R. & Hsueh, C. M. (2006). Knowledge map creation and maintenance for virtual communities of practice. Information Processing & Management, 42 (2), 551-568.

Martínez, D.; Martí, R. (2003). La factoría de recursos docentes. En Los Centros de Recursos del Aprendizaje y la Investigación en los procesos de innovación docente: Jornadas Rebiun 2003. Disponible en: http:biblioteca.uam.es/paginas/palma.html [Consultado el 05/04/06]

Milam, John H., Santo, Susan A. & Heaton, Lisa A. (2001). Concept Maps for Web-Based Applications. ERIC Technical Report. Disponible en: http://highered.org/docs/milam-conceptmaps.PDF. [Consultado: 16/2/2006].

Moreiro González, J. A. *et al.* (2002). Mapas conceptuales, topic maps y tesauros. [en línea]. En: *JOTRI 2002. I Jornadas de Tratamiento y Recuperación de la Información, 4-5 julio, 2002, Valencia*. Disponible en: <http://www.fundacion.uc3m.es/jotri2003/ponencias/mapas.pdf>. [Consultado: 9/02/2006].

Naumís Peña, C. (2001) Mapas conceptuales de los contenidos educativos en México En: La representación y organización del conocimiento: metodologías, modelos y aplicaciones: actas del V Congreso ISKO-España, 25-27 de abril de 2001, Alcalá de Henares, Madrid, 2001

Saadani, L.; Bertrand-Gastaldy, S. (2000). Cartes Conceptuelles et Thésaurus : Essai de Comparaison Entre Deux Modèles de Représentation Issus de Différentes Traditions Disciplinaires. ACSI 2000: Les dimensions d'une science de l'information globale.

Schawn Farris, J., Jones, K. S. & Elgin Peter D. (2002). Users' Schematic of Hypermedia: What Is so 'Spatial' about a Website?. Interacting with Computers, vol. 14, pp. 487-502.

Sancho, J. M. (2000). Diversificar los espacios de enseñanza. Cuadernos de Pedagogía, 290, p. 54-57.

Sherratt, C. S. & Schlabach, M. L. (1990). The application of concept mapping in reference and information services. RQ, 30, 60-69.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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MAPAS CONCEPTUALES: UN SENDERO METODOLÓGICO PARA LA DOCENCIA EN LA ENSEÑANZA TECNOLÓGICA

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Resumen: El uso de Mapas Conceptuales en la enseñanza superior ha sido bastante estudiado. Mientras tanto, su uso asociado a las actividades de aprendizaje cooperativo no ha sido explotado con frecuencia. El objetivo de este trabajo es el de compartir una experiencia de docencia en la educación superior a través de aplicación de mapas conceptuales asociado al uso de aprendizaje cooperativo en ambiente presencial. Inicialmente hacemos una breve revisión de la literatura sobre el surgimiento de los Mapas Conceptuales, pasando en seguida a considerar los estudios de Panitz (2004), Bruffee (2004) y de los hermanos Johnson (1999) a respecto de las diferencias entre las propuestas de aprendizaje cooperativo y colaborativo así como abordar algunas actividades cooperativas sugeridas por Campos (2003) y Slavin (1995). Después de esas consideraciones, describimos el trabajo desarrollado con alumnos de la disciplina Gestión de Materiales del Curso de Tecnólogo en Gestión de la Calidad de la Facultad CETEP en Curitiba, Brazil para en seguida presentar y analizar los resultados obtenidos.

1 Introducción

La enseñanza en el nivel superior muchas veces se coloca como un desafío para los docentes. Algunos alumnos ya ven con expectativas de actuación en sala de clase, tanto su papel como el papel del profesor. El uso de Mapas Conceptuales saca al alumno de su zona de confort. Su construcción demanda atención, dedicación, comprensión del contenido, uso de las habilidades de análisis y creatividad, en un debate de crecimiento personal. Por sí solo, el uso de la técnica de construcción de Mapas Conceptuales en la enseñanza-aprendizaje ya se coloca como una experiencia importante para el alumno. Cuando los Mapas Conceptuales son usados de forma cooperativa, el desequilibrio generado es todavía mayor. Los alumnos, además de debatir con el "cómo exteriorizar" su conocimiento, también trabajan con el "cómo socializar" este conocimiento y el "cómo aprender unos con los otros". En situaciones de aula de clase donde el contenido que se aprende es impartido sólo por el profesor, se colocan como grandes desafíos para los alumnos que deben cambiar su actitud frente al aprendizaje: el aprender con sus compañeros, saber oírlos y cuestionarlos, buscar en conjunto conceptos que mejor expresen contenidos y palabras de ilación que conecten esos contenidos de forma significativa.

En este trabajo, desarrollado en la disciplina de Gestión de Materiales del curso de Tecnólogo en Gestión de la Calidad, presentamos los resultados del uso de Mapas Conceptuales unido a actividades cooperativas. Describimos cómo las actividades fueron ejecutadas y analizamos el uso de los mapas Conceptuales, el papel del profesor y de los colegas, comparado con las clases convencionales, con la actividad de cooperación por si sólo y comparada con el método tradicional de enseñanza.

2 Mapas Conceptuales, un punto de partida

Aplicaciones prácticas del uso de Mapas Conceptuales han sido desarrolladas con estudiantes de varias franjas de edad, variando desde la enseñanza primaria, como en el trabajo presentado por Iraizo, Huarte y Gonzáles (2004, p.359) en la primera conferencia internacional sobre mapas conceptuales, hasta el amplio uso de la herramienta en la enseñanza superior.

La invención de los mapas conceptuales fue para Novak (2004, p.460) una resultante de las necesidades de él y de su equipo de transcribir la gran cantidad de datos reunidos en su trabajo de investigación. Novak habría encontrado el punto de partida para la creación de los mapas conceptuales en el trabajo de Ausubel sobre aprendizaje significativo. Según la interpretación de Novak fueron tres las ideas de Ausubel que llevaron a la creación de los mapas: la primera, el desarrollo de nuevos significados, construidos sobre conceptos relevantes y proposiciones; la segunda, la organización jerarquizada de las estructuras cognitivas, donde los conceptos más inclusivos ocupan los mayores niveles y la jerarquía y los conceptos menos inclusivos son subordinados a los conceptos más inclusivos; y la tercera, cuando el aprendizaje significativo ocurre, las relaciones entre los conceptos son más precisas y mejor integradas. Partiendo de las consideraciones mencionadas, podríamos considerar que los

mapas conceptuales serían una forma de expresión visual, que representarían el conocimiento construido por una persona sobre determinado asunto. La apreciación reflexiva de un mapa conceptual, sus conceptos, su jerarquía, las conexiones y preposiciones empleadas, permitirían una interpretación de la estructura cognitiva del constructor del mapa sobre un determinado tema

3 Mapas Conceptuales, una brújula

Para Novak, hasta la década de 1960 el pensamiento científico que predominaba era basado en los presupuestos *positivistas* y también en las ideas propuestas por Piaget. Según Novak, en esta década las líneas de la psicología sobre los procesos de aprendizaje eran fuertemente afectadas por las ideas de la psicología comportamental. Mientras tanto, no muy de acuerdo con esa línea teórica y sin conocimiento del trabajo de Piaget del inicio de 1926 en el cual él describe el desarrollo cognitivo de los niños a lo largo del tiempo, Novak (2004, p. 457) y su equipo fundamentan sus investigaciones en el trabajo de Ausubel (1963) sobre la psicología cognitiva. La experiencia conducida por ellos, que comenzó en 1965 y fue aplicada a partir de 1971 a lo largo de 13 años, se propuso responder a sus dudas de si niños de 6 a 8 años podrían aprender conceptos más complejos, enseñados tradicionalmente sólo años más tarde, contrariamente a los presupuestos piagetianos.

Considerando que el trabajo de Vigotsky sobre el concepto de zona de desarrollo proximal anticipó las ideas de Ausubel de que el aprendizaje significativo debería iniciar con lo que el alumno ya conoce, Novak (2004, p.464-465) recomendaría que el aprendizaje comenzase con niños en actividades de pequeños grupos. Para él, parte de eso resultaría de hecho de que estudiantes cooperativos estarían situados aproximadamente en un mismo nivel de comprensión y que éste nivel sería mucho mayor que el alcanzado con la forma convencional de aprendizaje. Así, para Novak, los estudiantes en aprendizaje cooperativo disfrutarían de una ventaja cognitiva sobre el abordaje de aprendizaje independiente como también sobre el aprendizaje competitivo.

4 Cooperación y Colaboración, un puente

Muchos investigadores han usado indistintamente los términos “cooperación” y “colaboración” como si fuesen sinónimos, sin preocuparse de posibles diferencias que puedan existir entre ellos y que pueden significar abordajes pedagógicos profundos y distintos. Un ejemplo puede ser visto en el trabajo de Campos et all cuando definen lo que es aprendizaje cooperativo: “El aprendizaje *cooperativo* es una técnica o propuesta pedagógica en la cual estudiantes se ayudan en el proceso de aprendizaje, actuando como compañeros entre sí y con el profesor, con el objetivo de adquirir conocimiento sobre un objeto determinado. La cooperación como apoyo al proceso de aprendizaje enfatiza la participación activa y la interacción tanto del alumno como de los profesores. El conocimiento es considerado como un constructor social, y de esta forma el proceso educativo acaba siendo beneficiado por la participación social en ambientes que propicien la interacción, la *colaboración* y la evaluación.” (Campos et all, 2003, p. 26 y 27).

Panitz (2004, p.1) propone otro acercamiento y procura esclarecer su punto de vista sobre las posibles diferencias entre cooperación y colaboración, que serían: en el modelo cooperativo el profesor mantendría el completo control de la clase. La cooperación sería una estructura de interacción designada para facilitar el cumplimiento de un determinado fin u objetivo a través del trabajo conjunto de alumnos; la colaboración sería una forma de filosofía de interacción entre las personas, así como un estilo de vida, donde los individuos son responsables por sus acciones, incluyendo el aprender, donde habría una preocupación mayor con respecto a las habilidades y contribuciones de sus compañeros. En el modelo de colaboración los alumnos asumirían la conducción de sus tareas.

Es importante resaltar que en ambos modelos los profesores asumirían el papel de mediadores del conocimiento. Esta postura de mediación correspondería al abordaje constructivista defendida por Brunner, Vigotsky, Piaget, Bruffee y otros.

Para Bruffee (2004, p.5), los modelos de aprendizaje cooperativo y colaborativo estarían conectados; donde el aprendizaje colaborativo - usado en colegios y universidades, por tanto asociado a la madurez de los alumnos - complementaría el aprendizaje cooperativo en el cual los niños experimentarían en las escuelas primarias, o sea, el aprendizaje colaborativo serviría como una concepción, un punto de continuación entre las dos metodologías. Los

principios generales permanecerían iguales en los dos modelos, sin embargo, con alteraciones en los énfasis y prácticas en los dos estilos de aprendizaje.

Otro punto puede ser observado de los estudios en los hermanos Johnson (1999, p.70 e 71). Los Johnson propusieron a través de una forma gráfica, una curva de desempeño que representaría el aprendizaje de los alumnos. En esta curva están dispuestos los niveles de desempeño en uno de los ejes y en el otro la efectividad de los grupos. Pueden ser divididas en fases donde tendríamos el resultado alcanzado por los alumnos individualmente, los diversos formatos de grupos iniciados por los pseudo-grupos, los llamados grupos tradicionales encontrados en las salas de clase, los grupo de aprendizaje cooperativo y finalmente los grupos de aprendizaje cooperativo de alto desempeño. Los hermanos Johnson advierten el hecho de que no todas las formas de grupos pueden ser llamadas grupos cooperativos. Colocar a las personas juntas no garantiza la realización del aprendizaje de forma cooperativa. Un pseudo-grupo sería aquel en el cual los alumnos serían colocados juntos para aprender juntos, pero no tendrían interés en hacerlo. Ellos podrían estar físicamente juntos, pero no estudiarían juntos, ni se ayudarían unos a los otros. Los alumnos interferirían y podrían hasta bloquear el aprendizaje unos a los otros. El resultado es que la suma de los trabajos de los alumnos sería menor que la suma de los trabajos individuales de esos resultando de aquí una ineficiencia del proceso de aprendizaje. Los investigadores definieron como *tradicionales* los grupos de aprendizaje encontrados frecuentemente en las salas de clase, como grupos donde los miembros aceptan trabajar juntos, sin embargo, verían como acciones que producirían pocos beneficios. Esto se caracterizaría por una interdependencia baja, donde los alumnos no tendrían mucha responsabilidad por el aprendizaje de los demás compañeros. Los grupos de aprendizaje cooperativo se caracterizarían por los resultados producidos como siendo mayor que la suna de los resultados individuales de sus participantes. En este tipo de grupo los alumnos estarían comprometidos con un propósito común que sería el de maximizar el aprendizaje unos a los otros. Johnson y Johnson proponen que un grupo de aprendizaje cooperativo tendría cinco características. La primera sería la motivación para alcanzar una meta que estaría por encima de su alcance. Esta motivación cargaría junto a la responsabilidad para con el propio resultado, el resultado de sus compañeros y finalmente el resultado del grupo. La responsabilidad sería la segunda característica, pues para los Johnson los miembros de los grupos necesitan creer que "**o nadan juntos o se consumen juntos**". La tercera característica sería la ejecución de los trabajos en forma conjunta. No se trata solamente de compartir informaciones y perspectivas, sino también de producir constructivamente en conjunto. La cuarta característica sería el uso de las habilidades sociales para coordinar sus esfuerzos y alcanzar sus resultados. Y la quinta característica estaría basada en el proceso de auto evaluación del grupo en cuanto al alcance de sus objetivos y en cuanto a la forma como ellos estarían apareciendo en los trabajos, o sea, una evaluación de los resultados y de los medios empleados para alcanzar esos fines.

Los grupos de aprendizaje cooperativo de alto desempeño serían aquellos que encontrarían todas las características arriba mencionadas y extrapolarían todas las expectativas iniciales. Para los Johnson las diferencias entre los grupos de alto desempeño y los grupos de aprendizaje cooperativo serían el elevado nivel de compromiso que los miembros alcanzarían entre sí y los resultados alcanzados.

5 Algunas actividades cooperativas

Según Campos et all (2003, p. 40 e 41) los métodos más comunes empleados en actividades de aprendizaje cooperativo serían: *El STAD* (Student Teams Achievenent Division), *Jigsaw*, Controversia Constructiva o Controversia Estructurada y la Investigación en Grupo.

Slavin (1995, p.5 a 11) profundiza el acercamiento a los métodos señalados anteriormente y propone los siguientes modelos: *Student Teams-Achievenent Divisions (STAD), Teams Games Tournament (TGT), Jigsaw, Team Accelerated Instruction, Cooperative Integrated Reading and Conposition (CIRC).* Además de esos métodos inicialmente citados encima por Slavin el autor menciona adelante en su libro otras posibilidades (1995, p.71) tales cono: *Group Investigation, Learning Together, Conplex Instruction, Structured Didactic Methods.*

Este estudio utilizó parcialmente algunas de las técnicas mencionadas, entre ellas:

5.1 Student Teams Achievenent Divisions - STAD

En esta técnica los estudiantes son separados en pequeños grupos de tres a cuatro alumnos. El grupo es estructurado de forma **heterogénea,** según el nivel de aprendizaje, género y factores sociales de los demás participantes. Se presenta un tema a los alumnos y ellos lo trabajan en sus grupos hasta que todos los participantes alcancen un adecuado nivel de aprendizaje. En ese punto los alumnos ya no deben realizar la tarea de forma cooperativa. Ahora los estudiantes responden de forma individual a preguntas formuladas por el profesor.

5.2 Teams Games Tounament – TGT

Ellos aplican la misma estructura grupal presentada en el STAD variando en la parte final cuando se organiza un concurso entre los equipos.

5.3 JIGSAW

Este método aplica la organización del grupo de forma semejante al STAD y TGT.
Se distribuye el mismo material de lectura para los grupos, sin embargo, el material se divide entre los alumnos del grupo de forma que cada alumno tiene apenas una parte del material, pero juntando todos los alumnos del grupo se tiene el conjunto completo. Los equipos se deshacen y los alumnos de los diferentes grupos que tienen el mismo material se sientan juntos para estudiar de forma cooperativa el tema. Estos alumnos también planean como presentar a los compañeros lo que estudiaron. Después se forman de nuevo los grupos originales y cada alumno explica a los demás lo que aprendió.

5.4 Teams Accelerated Instruction – TAI

Mientras el STAD y el TGT usan un solo método de aprendizaje para los alumnos el método TAI combina los abordajes cooperativo e individual. Los estudiantes deben resolver un problema por sí. Los colegas dan a conocer las respuestas unos de los otros y también ayudan a sus compañeros que están enfrentando problemas.

6 Una propuesta diferente, uniendo el punto de partida al puente, creando un camino posible

El inicio del semestre lectivo de la disciplina de Gestión de Materiales del curso de Tecnólogo en Gestión de la Calidad con los alumnos del tercer semestre, fue estructurado con base en el uso de la herramienta Mapas Conceptuales. En los ocho primeros encuentros fue usada la herramienta para la presentación del contenido de la disciplina y de su uso a los alumnos A pesar de que el profesor elaboró los MC, los alumnos participaron proponiendo conceptos asociados al tema. Es importante resaltar que el grupo es bastante heterogéneo, con alumnos provenientes en su mayoría de escuelas públicas, donde todos los alumnos tienen una significativa experiencia profesional acumulada y que el tema que se va a estudiar ya es de cierta forma conocido a través de la experiencia profesional, pero sin una profundización teórica, o sea, los alumnos ya tenían algunas opiniones formadas sobre los varios temas que serían abordados en el transcurso de la disciplina. Aproximadamente en el segundo tercio de la duración de la disciplina los alumnos pasarán a utilizar la herramienta, elaborando sus mapas conceptuales sobre los temas tratados. Los mapas eran sencillos y había diferencias significativas pues algunos alumnos consideraban que los mapas deberían simplificarse. Después se organizaron estructuras cooperativas de estudio en grupo y se pidió a los alumnos que produjesen los mapas en grupos, siguiendo orientaciones de forma cooperativa (estructurando actividades de acuerdo con los papeles propuestos - lector, revisor y redactor). Los alumnos no deberían avanzar sin que hubiesen llegado a un límite de comprensión compartido por todos los participantes "o todos nadan juntos o se consumen juntos". Después los alumnos presentaban los mapas para todo el grupo, ese era un momento de meta cognición, pues muchas fallas en el aprendizaje quedaron evidentes. Si comparamos la producción de los alumnos, podemos observar que en algunos de sus mapas iniciales existen pocos conceptos y ligaciones muy simples entre sí. Entre tanto, en la medida que ellos fueron adquiriendo más práctica, la calidad de los mapas fue evolucionando de manera que los mapas aumentaron de tamaño (inclusión de más conceptos) y de complejidad (aumento de conexiones).

Para este estudio fue propuesta una variación entre los métodos citados anteriormente, sin embargo en una combinación diferente. Como el número de alumnos que cursaban esa disciplina era de 15, fueron organizados cinco

grupos de tres alumnos cada. Se dividieron los temas de estudio en cinco partes proporcionales y cada una de estas partes fue pasada a uno de los grupos. Cada alumno debería estudiar individualmente el material recibido, generando su mapa conceptual, posteriormente, en grupo, de forma cooperativa presentaría su mapa a los compañeros y discutiría lo mismo, influenciando y siendo influenciado en una dinámica de enseñar y aprender, y después de que los alumnos alcanzasen un nivel de comprensión homogéneo ellos producirían un mapa, el cual representaría el resultado del aprendizaje ocurrido en el grupo. Posteriormente los alumnos cambiarían de grupo, ocupando entonces un papel de *especialista* en el asunto estudiado. En una actividad realizada en otro grupo entonces sería socializado el conocimiento adquirido a través de la presentación y discusión del tema El trabajo sería concluido con la elaboración y presentación del mapa final para toda la sala de clase. El papel del profesor sería el de trabajar como facilitador del aprendizaje, motivando el trabajo en grupo, acompañando las discusiones, manteniendo un ritmo y orientando a los alumnos, interpretando los mapas producidos, interviniendo cuando percibiese errores de conceptos, de preposiciones, de interconexiones y de también relacionamientos. Es importante resaltar que no se trataría de obtener un consenso entre los alumnos en la obtención y generación del mapa final, pero el mapa debería contener todo el aprendizaje obtenido, o sea, la conceptuación obtenida y la amplia red de preposiciones creadas. Los alumnos fueron orientados a no avanzar para las próximas etapas sin que hubiese el cuidado de asegurar que ningún alumno se quedó sin entender algún concepto estudiado.

Una variación de la técnica encima mencionada también fue efectuada a través de la actividad "responder a cuestionario", donde se podría tanto responder en grupo a una única cuestión propuesta por el profesor para cada equipo, como colectivamente a un mismo conjunto de cuestiones para todos los grupos. Correspondía a los alumnos siempre el compromiso de socializar el conocimiento adquirido con el grupo y la clase. No se permitió copiar las respuestas unos de los otros, pero sí de producirlas individualmente utilizando los conceptos aprendidos cooperativamente. El profesor evaluó la actividad continuamente durante todos los encuentros.

7 Presentación y análisis de resultados

La idea del proyecto era evaluar los resultados de la aplicación práctica de la herramienta Mapas Conceptuales en la enseñanza superior dentro de un abordaje cooperativo.

Fue construido un instrumento de investigación en el formato de cuestionario y de los 15 alumnos matriculados y que cursaban el módulo, 14 respondieron al cuestionario, lo que correspondió a 93% del grupo. Las respuestas están presentadas a continuación en forma de tabla. Las primeras preguntas están centradas más en el tema de los mapas conceptuales.

¿Usted considera que ha aprendido en esta disciplina?	Frecuencia	
	Absoluta	%
Sí, mucho.	8	57,1
Si, pero menos de lo que yo esperaba.	6	42,9
No he aprendido	0	0
No sé	0	0

Tabla 1 – Aprendizaje

¿Usted cree que el uso de mapas conceptuales facilitó su aprendizaje?	Frecuencia	
	Absoluta	%
Confundió	0	0
No facilitó	0	0
Facilitó poco	1	7,1
Facilitó significativamente	3	21,4
Facilitó mucho	10	71,4

Tabla 2 – Aprendizaje

Si comparamos las respuestas de la Tabla 1 con las respuestas de la Tabla 2 se puede observar que, en la opinión de los alumnos, el uso de los mapas conceptuales facilitó el proceso de aprendizaje y que además, generó una sensación de evolución en cuanto a ese proceso.

Las preguntas siguientes están más enfocadas en la cooperación. La misma pregunta fue hecha a los alumnos, enfocando los diversos agentes responsables por el aprendizaje de los mismos.

El profesor durante los encuentros cooperativos	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	0	0
Importancia media	1	7,1
Importante	3	21,4
Muy importante	10	71,4

Tabla 3 – Importancia de los Agentes de aprendizaje

El profesor durante las clases convencionales	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	0	0
Importancia media	0	0
Importante	5	35,7
Muy importante	9	64,3

Tabla 4 – Importancia de los Agentes del aprendizaje

Para los alumnos la figura del profesor aparece muy destacada en ambas aproximaciones, la cooperativa y la (digamos) clásica. La variación a las respuestas fue pequeña (sin embargo existió) y que puede ser interpretada como una mayor autonomía del alumno en relación con el profesor y el hecho del profesor asumir un papel de mediador, por tanto más próximo del alumno. Otra forma de verse sería el alumno (pasivo) atribuir al profesor una responsabilidad mayor por el aprendizaje de él (alumno).

Sus compañeros, durante los encuentros cooperativos.	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	0	0
Importancia media	2	14,3
Importante	5	35,7
Muy importante	7	50,0

Tabla 5 – Importancia de los Agentes del aprendizaje

Sus compañeros durante las clases convencionales.	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	4	28,6
Importancia media	3	21,4
Importante	7	50,0
Muy importante	0	0

Tabla 6 – Importancia de los Agentes del aprendizaje

En este punto podemos ver una variación muy significativa en cuanto al empleo del abordaje cooperativo y de la importancia que este pasa a tener para los alumnos en relación con el método tradicional de enseñanza. 29% de los alumnos creen que los compañeros tienen poca importancia en las clases tradicionales mientras que la misma

cuestión fue evaluada como 0% en el modelo cooperativo. Podemos además percibir que en el modelo tradicional 0% creen a los compañeros muy importantes contra 50% en el modelo cooperativo.

Yo, estudiando la literatura recomendada de forma autodidacta.	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	0	0
Importancia mediana	3	21,4
Importante	9	64,3
Muy importante	2	14,3

Tabla 7 – Importancia de los Agentes del aprendizaje

Yo, durante las clases cooperativas.	Frecuencia	
	Absoluta	%
Sin importancia	0	0
Poco importante	0	0
Importancia mediana	0	0
Importante	7	50,0
Muy importante	7	50,0

Tabla 8 – Importancia de los Agentes del aprendizaje

Aquí también podemos ver una significativa diferencia en la percepción de los alumnos cuando comparamos los dos métodos cuando el auto-estudio es realizado de forma independiente y cuando este auto-estudio es compartido, discutido y socializado cooperativamente con los demás alumnos.

Cómo percibe usted la variación de su aprendizaje utilizando el método (mapas conceptuales y abordaje cooperativa) en relación con el método tradicional de enseñanza.	Frecuencia	
	Absoluta	%
Estoy aprendiendo menos de lo que si fuese con el método tradicional	1	7,1
Los métodos son iguales en términos de aprendizaje, por tanto no hay variación.	0	0
De 0% a +10%	1	7,1
De +10% a +20%	2	14,3
De +20% a +30%	3	21,4
Más de 30%	7	50,0

Tabla 9 – Variación del aprendizaje

Aquí percibimos que apenas un alumno piensa estar aprendiendo menos de la forma cooperativa que de la forma tradicional y que el 93% perciben que están aprendiendo más que si fuese en la forma tradicional la mitad del grupo evalúa que su aprendizaje aumentó en más de 30% en relación con el modelo convencional de enseñanza.

De una manera general, podemos observar una elaboración cuidadosa de las respuestas dadas al cuestionario aplicado, con contribuciones profundas y reflexivas. En los comentarios de los alumnos se observó tanto una percepción del desarrollo de sus habilidades interpersonales como de su papel como un contribuidor responsable y activo y del papel del profesor como un guía ("Creo que además de mejorar mi relación con los compañeros, facilitó mi aprendizaje."; "Durante los encuentros cooperativos es de alta importancia la presencia de todos los compañeros para el desarrollo del grupo y la presencia del profesor para orientar, corregir y/o direccionar, etc...";) además de un mejor conocimiento de su propio proceso meta cognitivo ("Sé que puedo también trabajar en el sistema convencional, pero en la forma cooperativa nosotros tenemos varias ideas, con esto mezclamos a nuestro conocimiento agregando muchos valores. El trabajo en equipo funciona en forma más rápida y precisa". "En nuestros encuentros cooperativos mis compañeros y yo tenemos un aprendizaje igual."; y "en el convencional, la información está dirigida a lo que el profesor tiene como verdad. En el cooperativo la información viene de todos los lados, profesor y alumnos.").

8 Conclusiones

El uso de Mapas Conceptuales en ambiente cooperativo causó cierto desaliento inicial en los alumnos, pues se trató de un cambio significativo en su forma de estudiar arraigada por el paradigma vigente en la educación. Es necesario recordara que el paradigma vigente está organizado teniendo al profesor en el centro del proceso, en el sistema *yo enseño*. La propuesta adoptada transfiere al alumno la responsabilidad por el aprendizaje donde el énfasis pasa a ser el *yo aprendo*. El proceso cooperativo, a través de los datos reunidos se ha mostrado más eficiente que el modelo convencional, sin embargo una gran dificultad está enganchado al vínculo que los alumnos necesitan desarrollar una fuerte interdependencia, pues el resultado probó que el ausentismo en algunos equipos fue resultado de un prejuicio. El uso de los mapas permitió que el proceso de socialización del conocimiento se presentase de forma más rica, más inclusiva, más intensa, como consecuencia de una mayor actuación participativa de los alumnos, debatiendo los conceptos y la forma en que estos se relacionaban. Durante la presentación de los trabajos fue frecuente la re-elaboración de los mapas por parte de los alumnos, a través de un feedback directo, demostrando una postura de aprendizaje dinámica que más de una vez rompe con las prácticas convencionales. Se puede concluir de esa experiencia de trabajo con los mapas conceptuales de forma cooperativa que hubo un enriquecimiento del proceso enseñanza-aprendizaje como un todo no sólo por la concientización de los alumnos como responsables por su propio aprendizaje sino también por la importancia de su actuación en relación con el aprendizaje de sus compañeros.

9 Referencias

Bruffee K. A. (2006). *Sharing your toys: Cooperative learning versus collaborative learning***,** En: http://www.findarticles.com/p/articles/mi_m1254/is_n1_v27/ai_16739700, accesado en 03/02/2006.

Campos F. C. A., Santoro F. M., Borges M. R. S., Santos N. (2003). *Cooperação e aprendizagem on-line***,** DP&A Rio de Janeiro.

Cañas A. J., Novak J. D., González F. M., Eds. (2004). *Concept Maps: Theory, methodology, technology,* Proceedings of the First International Conference on Concept Mapping, Pamplona, España: Dirección de Publicaciones de la Universidad Pública de Navarra.

Cohen E. G., Brody C. M., Shevin M. S. eds. (2004). *Teaching Cooperative Learning: The Challenge for Teacher Education***,** State University of New York Press.

Foyle H. C., Ed. (1995)**.** *Interactive Learning in the Higher Education Classroom***,** National Education Association of the United States, Washington D.C.

Iraizo, N; Huarte, C. P. Mª; Gonzáles F. Mª (2004). *Los Mapas Conceptuales como agentes facilitadores del desarrollo de la inteligencia en alumnos de enseñanza primaria***,** En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra.

Johson D. W., Johson R. T. (1999). *Learning Together and Alone: Cooperative, competitive and individualistic learning*, 5ª edition Allyn and Bacon Massachusetts.

Johson D. W., Johson R. T, Smith K. A. (1992). *Cooperative Learning: Increasing College Faculty Instructional Productivity – ASHE ERIC Higher Educational Report nº 4*, The George Washington University, School of Education and Human Development, Washington D.C.

Novak, J. D. (2004*). A Science education Research Program that led to the Development of the Concept Mapping tool and a new model for education***.** En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra.

Marriott, R. C. V., Torres, P. L. (2005). *Tecnologias educacionais e educação ambiental: O uso de mapas conceituais no ensino e na aprendizagem*, Curitiba: FAEP.

Minguet, P. A., Org. (1998). A construção do conhecimento na educação. Porto Alegre, Artmed.

Panitz T. (2004). *Collaborative versus cooperative learning – A comparison of the two concepts which help us understand the underlying nature of interactive learning*, En: http://home.capecod.net/~tpanitz/tedsarticles/coopdefinition.htm, accesado en 13/10/2004.

Salvin, R. E. (1995). *Cooperative Learning – Theory, research and practice*, 2ª edicion, Allyn & Bacon: Massachusetts.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

MODELO UNIFICADO DE REPRESENTACIÓN DE CONOCIMIENTO EN MAPAS CONCEPTUALES Y ONTOLOGÍAS

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Resumen. Se presenta una propuesta de integración entre un modelo conceptual gráfico, como es el caso de los mapas conceptuales, y ontologías codificadas en el lenguaje OWL. Los mapas conceptuales son una forma flexible de representación del conocimiento, muy útil en entornos de colaboración de humanos; OWL es un lenguaje de representación del conocimiento orientado a análisis semántico por parte de máquinas. La integración consiste en un conjunto de métodos de transformación entre mapas conceptuales y el correspondiente código OWL, en los dos sentidos. Estos métodos incluyen algunos procedimientos de eliminación de ambigüedades existentes y otros nuevos.

1 Introducción

En la representación del conocimiento orientada al análisis semántico por parte de máquinas (un contexto en el que se necesita cierto grado de formalidad) se está viendo cada vez más en ascenso el desarrollo y utilización de las ontologías. La formalización de ontologías por parte de diferentes agentes genera normalmente el surgimiento de conflictos en las conceptualizaciones que se pueden solucionar mediante la colaboración del hombre o por medio de métodos automatizados en casos simples (Hayes et al., 2003). Los procesos de diseño y creación de ontologías, así como las herramientas disponibles para su mantenimiento, como por ejemplo Protégé (The Protégé Project, 2000), son aún complejos para personas no expertas en el tema. Si a esto se le añade la complejidad inherente a los lenguajes de especificación, se puede afirmar que hoy existe cierta dificultad para la creación de un ambiente colaborativo para el desarrollo de ontologías por parte de personas no expertas.

Lo anterior sugiere la utilización de otra forma de representación, que de forma integrada con las ontologías pueda ser utilizada con naturalidad por el hombre y a la vez mantenga las características de poder ser interpretada computacionalmente. Se propone aquí la utilización de los **mapas conceptuales (MC)** como forma de representación a integrar con las ontologías. Los MC son una herramienta definida para el aprendizaje del hombre, de fácil construcción, flexible e intuitiva para el hombre. Teniendo en cuenta todo esto y a pesar de su bajo nivel de formalización, se ha logrado una integración de los MC con las ontologías, específicamente con aquellas codificadas en OWL (acrónimo del inglés *Web Ontology Language*, un lenguaje de marcado para publicar y compartir datos usando ontologías en Internet), facilitando así la gestión del conocimiento por parte de humanos. En este artículo se resumen los primeros resultados de dicha integración, que denominaremos *modelo unificado* (MU) y que está constituido de procedimientos de transformación de MC a OWL, y viceversa. Estos procedimientos incluyen la especificación de la formalización de los MC y algoritmos de desambiguación.

2 Las ontologías y sus lenguajes

En el campo de la inteligencia artificial, las ontologías fueron definidas para compartir y reutilizar conocimiento. Aportan un lenguaje de comunicación necesario en entornos distribuidos que involucran agentes software, como la Web semántica, y una descripción semánticamente formal para el procesamiento del conocimiento. Según la definición de Ceccaroni (2001), derivada de Gruber (1993), Borst (1997) y Studer et al. (1998), una ontología (o mapeo semántico) es *una especificación formal y explícita de una conceptualización compartida, orientada a análisis automático por parte de máquinas.* En sentido general, una ontología es la base del procesamiento semántico; es una red de **conceptos, relaciones y axiomas** para representar, organizar y entender un dominio de conocimiento; proporciona el marco de referencia común para todas las aplicaciones en cierto entorno. Los orígenes de las formalizaciones ontológicas se encuentran en las redes semánticas (RS) y la teoría de marcos de Minsky (1975), y en lenguajes como Ontolingua (Farquhar et al. 1995) y DAML+OIL (DARPA, 2001), entre otros, la mayoría de los cuales están basados en el más sencillo RDF. La última evolución de los lenguajes para codificar ontologías consiste en la definición de OWL (Smith et al, 2004), para el cual existen tres especificaciones, con

diferentes niveles de expresividad: OWL Lite, OWL DL y OWL Full. El modelo que se propone en la presente investigación tiene un alcance aplicable tanto a OWL Lite como a OWL DL.

3 La integración entre mapas conceptuales y ontologías: el modelo unificado

El MU propuesto se puede entender como la integración de un lenguaje gráfico poco formal (MC) y un sistema de ontologías codificado en el lenguaje formal OWL, un lenguaje de gran complejidad de interpretación por personas no expertas. Los MC fueron definidos dentro de la pedagogía y responden a una notación gráfica que ayuda a que el conocimiento pueda ser fácilmente compartido, manipulado e interpretado por los seres humanos. Desde el punto de vista estructural, existe una gran similitud entre MC, RS y ontologías basadas en RDF, siendo estas últimas más formalizadas: el lenguaje RDF está formalizado mediante *triples* (*sujeto, predicado, objeto*) mientras los MC usan la estructura de *proposiciones* (*nodo, palabra-enlace, nodo*).

Como base inicial de la integración entre MC y ontologías, se realizó un estudio comparativo entre sistema de representación estructurados de manera similar: las RS, los sistemas de marcos y del lenguaje RDF. Se encontró que para una integración entre MC y ontologías es necesaria una mayor formalización de las *palabras-enlace* (p-e), ya que son el elemento sintáctico que define el tipo de relación existente entre los conceptos, elemento imprescindible para la obtención del código OWL. Los resultados alcanzados en el análisis de las diferentes formas de representación del conocimiento permitieron definir que hay una correspondencia directa entre las *clases* y *propiedades* en las ontologías, y los *conceptos* y *relaciones* en los MC. Conjuntamente, se han agrupado las relaciones de los MC por categorías de p-e, que deben satisfacer las necesidades semánticas requeridas para la obtención del código OWL. Específicamente, se proponen las siguientes categorías de p-e:

Categorías	Ejemplos de palabras-enlace
Subclasificación (CSC)	es_un[-1], tiene_por_subclase, tiene_parte_a, tiene_dependencia, incluye, agrupa, se_compone_de, comprende_a, puede_ser
Instanciación (CI)	tiene_por_instancia, instancia_como, tiene_ejemplo, instancia_de
Propiedad (CP)	tiene, posee, tiene_propiedad, toma_valor, tiene_valor, se_compone_de
Propiedad-Valor Directa (CPVD)	Sustantivos, por ejemplo: tipo, pared, rueda, etc.
Propiedad-Valor Indirecta (CPVI)	Formas Verbales, por ejemplo derivadas de: contener (contenido), ejercer (ejerce), representar (representa), etc.

Tabla 1. Categorías de palabras de enlace

En esta propuesta de p-e se ha tenido en cuenta la posibilidad de relacionar dos conceptos en las dos direcciones, incluyendo un conjunto de p-e simétricas ha algunas de las incluidas en esa categoría pero a ser utilizadas en el sentido contrario, tal es el caso de: es_un e instancia_de. Lo anterior es de gran utilidad ya que amplía las posibilidades de relación entre conceptos, por ejemplo: (Auto, tiene_ejemplo, Fiat 126p) y (Fiat 126p, instancia_de, Auto); (Auto, agrupa, Fiat) y (Fiat, es_un, Auto).

La cuestión principal aquí está en *¿cómo identificar la semántica que transmite la p-e que se utiliza para construir el código OWL?* Una solución que se propone es la de analizar al MC como un texto estructurado, ya que, a pesar de que responde a una forma gráfica de representación de conocimiento, cada una de las proposiciones en el incluidas es una frase en lenguaje natural. Es posible así complementar el MU con la aplicación de técnicas de *procesamiento de lenguaje natural* (PLN), como es el caso de algoritmos de desambiguación léxica para, a partir del sentido correcto de cada concepto del MC, determinar la naturaleza de las relaciones entre ellos, centrando la atención en las relaciones del tipo: *hiperonimia*[1]*-hiponimia*[2], *meronimia*[3]*-holonimia*[4] (Fellbaum, 1998). La integración entre el MC (lenguaje visual) y OWL (lenguaje formal) se puede formular como un proceso de

[1] Relación semántica de inclusión entre unidades léxicas, que va de lo más general a lo más específico.
[2] Relación semántica de inclusión de unidades léxicas que va de lo más específico a lo más general, lo opuesto de *hiperonimia*. Ej: "perro" se encuentra en relación de hiponimia con "animal".
[3] Relación semántica asociada a: parte de, es sustancia de, es miembro de, etc. Ej: X es merónimo de Y si X forma parte de Y; si X es una sustancia de Y; si X es un miembro de Y; por ejemplo: "azul" es merónimo de "color"; "doctor" es merónimo de "oficio"; "dedo es un merónimo de mano".
[4] Relación semántica opuesta a la meronimia, Ej: "bicicleta" es un holónimo mientras que "sillín" y "pedal" son merónimos de bicicleta.

transformación bidireccional; mecanismos complementarios de PLN para el análisis del MC contribuyen a que este no pierda una de sus principales bondades para el hombre que es su flexibilidad.

4 Algoritmos de desambiguación

El procedimiento que propone la presente investigación para la desambiguación de los conceptos en MC es una adaptación del procedimiento de Pons-Porrada et al. (2003), agregando algunos elementos de la propuesta de Cañas et al. (2003), como la medida de distancia entre conceptos para definir el contexto. El MU se basa en estos y otros trabajos previos y en la ontología léxica orientada a análisis por parte de máquinas WordNet (Fellbaum, 1998). WordNet tiene una estructura basada en *synsets* (conjuntos de uno o más sinónimos) relacionados como en una RS, los cuales están relacionados por medio de diferentes tipo de relación (*sinonimia*, *antonimia*[5], *hiperonimia*, *meronimia*, *implicación, etc.*). Cada *synset* tiene asociado uno o varios dominios muy útil en el proceso de desambiguación (Magnini et al., 2002, Pons-Porrada et al., 2003). Se pueden mencionar dos aspectos que, a opinión de los autores, son de gran importancia en un proceso de desambiguación conceptual en un MC: (1) el trabajo con los dominios a los cuales pertenecen los conceptos, en correspondencia con los *Dominios de Magnini* (Magnini et al., 2002) y (2) el uso de la mayor cantidad de tipos de relación de las presentes en WordNet. Ambos aspectos permiten aumentar la precisión en la identificación del sentido de un concepto dentro de un contexto y contrarrestan en alguna medida las limitantes presentes en las ontologías léxicas, particularmente en lo referente a la cantidad de términos almacenados. En el trabajo se utiliza un WordNet en español incluido en EuroWordNet (Vossen, 1997), para extender su campo de aplicación a este idioma.

En este sentido la propuesta descrita en (Cañas et al. 2003) muestra algunas limitantes, por ejemplo: no hace uso de los dominios y se utilizan solo relaciones de *hiperonimia*, además no especifica como se lleva a cabo la desambiguación del *concepto-principal*. Por el contrario, en el procedimiento de desambiguación descrito en (Pons-Porrada et al. 2003) sí se tiene en cuenta los dominios asociados a cada *synset* y una mayor cantidad de tipos de relación, sin embargo su aplicación directa a un MC no aprovecharía la simplificación de la complejidad de ese proceso que se pudiera lograr a partir del hecho de que un MC muestra una estructura resumida de un texto. El procedimiento propuesto en la presente investigación se describe a continuación.

Sea la notación $\boldsymbol{C_c(c)}$ el contexto de un concepto ***c*** en un MC que tiene por significado: el conjunto de conceptos que están incluidos en las proposiciones del MC en las se encuentra ***c*** y aquellos que se encuentran a una distancia $\boldsymbol{D = 2}$ a partir de ***c***. Siendo ***D*** la distancia del camino (proposición) a recorrer de un concepto **c1** a un concepto **c2** cualquiera. Sean $\boldsymbol{G = <S, R>}$, el grafo no orientado asociado al grafo de WordNet y $\boldsymbol{s \in S}$, un *synset*. Llamaremos *d-vecindad* de ***s*** al conjunto de todos los *synset* ***s'*** tal que existe una cadena de ***s*** a ***s'***, siendo ***d*** la distancia a recorrer de ***s*** a ***s'*** en ***G.*** En acuerdo con Pons cada relación semántica de WordNet tiene un impacto diferente en la desambiguación de un término, por tal razón se ha tomado la función de peso $w(R)$ sobre dichas relaciones que se propone en (Pons-Porrada et al, 2003): se asigna un peso de 10 a la relación de *sinonimia*, 8 a las relaciones *near_synonym*, *xpos_near_synonym*, 5 a las de *hiperonimia* o *meronimia*, 1 a la de *antonimia*[5] y 2 a las restantes. La votación que recibe un *synset* ***s*** del concepto ***c*** con respecto al contexto $\boldsymbol{C_c(c)}$ y la *d-vecindad* de ***s*** se define como:

$$V_s(C_c, d) = \sum_{s' \in \Omega}^{d} v(s')/d$$

Donde $\Omega = C_c(c) \cap d\text{-}vecindad(s)$ y $v(s') = \prod_{j=1} w(R_j)$

siendo R_j las relaciones que etiquetan las aristas que forman el camino de longitud ***j*** entre ***s*** y ***s'***.

Relacionar los synsets a los conceptos del MC.

1. Asignar a cada concepto ***c*** una lista de todos los *synset* ***S(c)*** en los que aparece en WordNet e incorporarlos a una lista de *"Conceptos no desambiguados"* (CND).
2. Se pasa a una lista de *"Conceptos ya desambiguados"* (CD) todos aquellos conceptos que tengan un solo *synset* en ***S(c)*** conjuntamente con el *synset* correspondiente.

Determinar el dominio del concepto-principal.

3. Si *concepto-principal* ∈ CD
   entonces:

[5] Relación semántica de oposición entre los significados de dos palabras: las palabras "útil" e "inútil" tienen una relación de antonimia.

a. ese dominio sería el correspondiente a ese *synset* y será identificado como DCP (Dominio Concepto Principal)

si no:

b. Para cada $s \in S(c)$ calcular su votación ($V_s(C, d)$). El synset correspondiente al *concepto-principal* sería el que mayor votación tendría. En este caso DCP sería el dominio correspondiente al *synset* resultante que coincida con el que más se repita dentro de los s' incluidos en *d-vecindad(s)*. Es poco probable que varios synsets tengan la misma votación, en ese caso se tomaría como DCP el dominio incluido en cada uno de ellos que más se repita dentro del conjunto de s' incluidos en esa vecindad.

Desambiguar por el dominio.

4. Para cada concepto $c \in CND$, si alguno de sus $s \in S(c)$ incluye por dominio a DCP**,** pasar este concepto conjuntamente con ese *synset* a la lista de CD.

Desambiguar los conceptos pendientes (en caso de que CND no esté vacía).

5. Para cada $c \in CND$**,** realizar el mismo procedimiento relacionado con la votación de los *synset* $s \in S(c)$ correspondiente a cada concepto c que se describe en el paso 3b.

5 El proceso de transformación en el Modelo Unificado

En la explicación del proceso de transformación que se proponen en el MU serán utilizados los dos ejemplos de MC que se muestran en las siguientes figuras. El primero (Figura 1) es un MC de un domino general dentro del contexto de la anatomía del cuerpo humano y el segundo (Figura 2) es un MC obtenido de un fragmento de la ontología *Activities.owl* utilizada en el contexto del proyecto @LIS TechNET[6] (Ceccaroni et al., 2005).

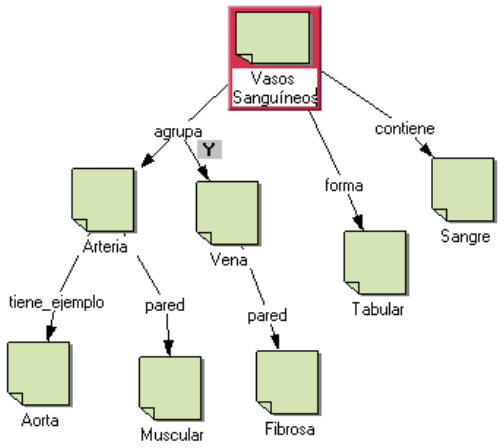


Figura 1. Mapa conceptual de un dominio general (Vasos Sanguíneos)

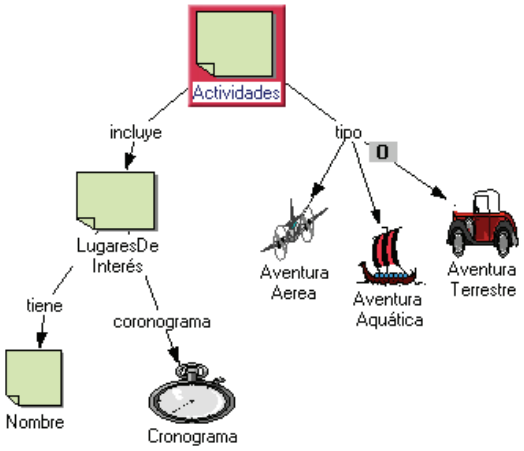


Figura 2. Mapa conceptual obtenido de un fragmento de la ontología Activities utilizada en el proyecto @Lis TechNET.

5.1 La obtención del OWL a partir del MC

Fase 1. Desambiguación de conceptos. En esta etapa inicial se realiza el proceso de identificación de los sentidos correctos de todos los conceptos del MC utilizando el método descrito en la sección anterior. Al culminar el proceso, se tendrá el dominio al que pertenece el MC que generalmente se corresponde con el del *concepto-principal* y que a su vez debe coincidir con el que más se repite entre los conceptos del MC, aunque esto depende mucho del nivel de especialización del conocimiento. Además del dominio del MC se conocen los sentidos (*synset*) de todos o la mayoría de los conceptos del MC, también en dependencia del nivel de especialización del MC. Con esta información se pasa la próxima fase con una lista **LP** que incluye todas las proposiciones que conforman el MC y cada concepto es acompañado de su *synset*.

[6] Proyecto @LIS TechNET del programa EuropeAid [http://europa.eu.int/comm/europeaid/projects/alis/index_es.htm]

Fase 2. Conceptualización y lista de términos OWL. Todos los *nodos-conceptos* son expresados inicialmente como *clases* en OWL (*owl:Class*). Tomando como ejemplos a conceptos que se muestran en la Figura 2 la codificación en OWL sería:

```
<owl:Class rdf:ID = "Actividades">
    <rdfs:subClassof rdf:resource = "Thing">... />
<owl:Class rdf:ID = "Aventura Aerea">
    . . .
```

El *concepto-principal*, en este ejemplo "Actividades" se expresa como *subclase* de la clase "Thing" (clase más abstracta dentro de de cualquier ontología).

Fase 3. Identificación de las Relaciones de Subclasificación. Para cada proposición **p ∈ LP** con sintaxis (c1, p-e, c2):

1. Si **p-e ∈ CSC**, **c1** es expresado en OWL como clase y **c2** como subclase de **c1**. Codificación en OWL utilizando como ejemplo el MC de la Figura 1:

```
<owl:Class rdf:ID = "Vena" >
    <rdfs:subClassOf rdf:resource = "Vasos Sanguíneos" />
        . . .
```

2. Si **p-e ∉ CSC** es necesario recurrir al uso de WordNet.
   Sea **s1** y **s2** los sentidos de **c1** y **c2** respectivamente:
   a. Generar todas las cadenas de *synset* de relaciones de *hiponimia* a partir de **s1** y almacenarlas en la lista **LHipo(c1)** y todas las cadenas de *synsets* de relaciones de *hiperonimia* a partir de **s2** y almacenarlas en la lista **LHiper(c2)**
   b. Si **s2 ∈ LHipo(c1)** o **s1 ∈ LHiper(c2)**, significa que existe algún camino de *hiponimia* o de *hiperonimia* entre **s1** y **s2** respectivamente, lo cual permite inferir que **c2** es una *subclase* de **c1.**

   Esto se puede comprobar en las proposiciones (Vaso Sanguíneo, agrupa, Arteria) y (Vaso Sanguíneo, agrupa, Vena) en MC de la Figura 1, donde Arteria y Vena tienen una relación de *hiponimia* con Vaso Sanguíneo y se codificaría en OWL de la misma forma que se muestra en el punto anterior.

Fase 4. Identificación de las Relaciones de Instancia. Se hace cuando en las proposiciones con sintaxis (c1, p-e, c2) **p-e ∈ CI** y **c2** es un concepto hoja (no se encuentra en ninguna proposición como concepto origen) y se codificaría en OWL a **c2** como una *instancia* de **c1**. Tomando como ejemplo la proposición (Arteria, tiene_ejemplo_a, Aorta) (Ver Figura 1.) el código OWL que se genera sería:

```
<owl:Class rdf:ID = "Arteria">
    ...
<Arteria  rdf:ID = "Aorta" >
    ....
</Arteria>
```

Fase 5. Identificación de las Relaciones de Propiedad. Dada la proposición **p ∈ LP**, con sintaxis (c1, p-e, c2):

1. Si **p-e ∈ CP**, se interpretaría con una sintaxis (clase, p-e, propiedad) y se puede inferir que **c2** es una es un tipo de propiedad de **c1.** Utilizando la proposición (LugaresDeInterés, tiene, Nombre) incluida en el MC de la Figura 2 la codificación sería:

```
<owl:Class rdf:ID = "LugaresDeInterés" >
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty>
                <owl:DataTypeProperty rdf:ID = "Nombre"/>
            </owl:onProperty>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

2. Si **p-e ∈ CPVD**, se interpretaría con una sintaxis (clase, propiedad, valor) y se puede inferir que la p-e es una propiedad de **c1** y c2 es el valor que toma dicha propiedad. Un ejemplo de esta situación sería la proposición (LugaresDeInterés, conograma, Cronograma) y la codificación en OWL sería:

```
<owl:ObjectProperty rdf:about = "#cronograma">
   <rdf:type rdf:resource="&owl; FunctionalProperty"/>
   <rdfs:domain rdf:resourse="#LugaresDeInterés"/>
   <rdfs:range rdf:resourse="#Cronograma"/>
</owl: ObjectProperty>
```

Si no existe otra relación de **c1** con otro concepto por medio de la misma **p-e**, se puede inferir que la propiedad podrá tomar un solo valor por lo que se ha considerado incorporar a la codificación de la propiedad la característica: *<rdf:type rdf:resource="&owl; FunctionalProperty"/>*

3. Si **p-e ∈ CPVI**, se interpretaría con una sintaxis (clase, propiedad indirecta, valor) y se puede inferir que **c2** es el valor de la propiedad derivada de la **p-e** y perteneciente a **c1** y su codificación en OWL sería, tomando como ejemplo la proposición (Vasos Sanguíneos, contiene, Sangre) de la Figura 1:

```
<owl:Class rdf:ID = "Sangre"> . . . </owl:Class>
<owl:ObjectProperty rdf:ID = "contenido">
        <rdfs:domain rdf:resource = "#Vasos Sanguíneos"/>
        <rdfs:range rdf:resource = "#Sangre"/>
</owl:ObjectProperty>
```

En el MC pueden existir relaciones no binarias, como sucede en el caso de la Figura 1. Esta situación en particular es interpretada como que una propiedad puede tener asociado al menos uno de los que relaciona la **p-e**, y sería codificado en OWL de la siguiente forma:

```
<owl:Class rdf:ID = "Actividades">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource = "#tipo">
      <owl:someValueFrom rdf:resource = "#Aventura
      Aerea"/>
       <owl:someValueFrom rdf:resource = "#Aventura
      Terrestre"/>
       ....
</owl:Class>
```

En Gómez et al. (2004) se tiene en cuenta este mismo criterio pero para todos los tipos de propiedades, no siendo así en nuestro caso.

4. Si **p-e ∉ {CP, CPVD, CPVI}** es necesario recurrir al uso de WordNet.
   Sea **s1** y **s2** los sentidos de **c1** y **s2** respectivamente:
   a. Generar todas las cadenas de *synset* de relaciones de *meronimia* a partir de **s1** y almacenarlas en la lista **LMero(c1)** y todas las cadenas de *synset* de relaciones de *holonimia* a partir de **s2** y almacenarlas en la lista **LHolo(c2)**
   b. Si **s2 ∈ LMero(c1)** o **s1 ∈ LHolo(c2)**, significa que existe algún camino de *meronimia* o de *holonimia* entre **s1** y **s2** respectivamente**,** lo cual permite inferir que entre **c1** y **c2** existe una relación de propiedad. La propiedad pertenece a **c1**, es identificada como la **p-e** y toma como valor a **c2**. La codificación en OWL coincide con lo expresado en el punto 2 dentro de esta misma fase.

5.2 La obtención del MC a partir de OWL

La obtención de un MC a partir de código OWL se realiza a través de las cinco fases siguientes:

1. Representación de la arquitectura básica. Según las convenciones vistas, las clases (*owl:Class*) y las instancias (X *rdf:ID="Y"*) se representan como conceptos en el MC.

2. Identificación del concepto-principal. El *concepto-principal* corresponderá a aquella *clase* que solo sea *subclase* de "Thing" y no sea una *propiedad* de ninguna *clase* o *subclase*. En caso de que exista más de una clase que cumpla con estos requerimientos, donde es mayormente frecuente que suceda en contextos muy generales, se seleccionaría la clase que más subclases tendría.

3. Representación de relaciones entre *clases* y *subclases*. Se crean enlaces dirigidos, del nodo correspondiente a la *clase* al nodo correspondiente a la *subclase* y el enlace sería etiquetado con cualquiera de las *palabras-enlaces* incluidas en **CSC**.

4. Representación de las relaciones de instancia. Se crean enlaces dirigidos, del *nodo-concepto* asociado a la instancia en OWL al concepto asociado con la clase a la que corresponde dicha instancia. El enlace es etiquetado con cualquiera de las *palabras-enlaces* incluidas en **CI**.

5. Identificación de las relaciones según las propiedades (*owl:ObjetcProperty*). Una propiedad puede tener uno o varios valores. En el primer caso, pueden ser expresada mediante en una proposición en el MC: los términos especificados en *rdfs:range* y en *rdfs:domain* serían los conceptos, siendo el origen el concepto especificado en *rdfs:domain,* y la *palabra-enlace* sería el término especificado en *owl:ObjectProperty*. En el segundo caso, se crearía un *nodo-concepto* por cada uno de los elementos especificados con *owl:someValueFrom,* también se representaría con un *nodo-concepto* la clase a la cual corresponde dicha propiedad y se crearía una relación dirigida a cada uno de los nodos-conceptos creados por la especificación de *owl:someValueFrom* , con origen en el nodo-concepto asociado a la clase y con una *palabra-enlace* compartida especificada según el término usado en *owl:onProperty*.

6 Implementación y trabajo futuro

Los procedimientos descritos han sido implementados en lenguaje C++. El proceso de transformación implementado parte de tener un MC del que sea posible generar una representación en XML o una ontología codificada en OWL en dependencia de cual sea la dirección de la transformación. En el caso de MC, este es elaborado con la herramienta MACOSOFT (Simón, 2006) y por medio de ella misma es generado el código XML correspondiente con un formato específico; con respecto a la ontología en OWL, puede ser obtenida de alguna de las herramientas para la construcción de ontologías existentes. Las fases concebidas en cada uno de los procedimientos de transformación son ejecutadas internamente de forma iterativa e incremental. Se cuenta con una versión de WordNet en español la cual es consultada durante el proceso de transformación por el componente. Los resultados preliminares obtenidos de las pruebas realizadas se ven reflejados en los ejemplos utilizados aquí. Se pueden dar casos en los cuales el proceso de transformación fracasa. Uno de estos casos es cuando se consulta WordNet y no se encuentra ningún *synset* que se corresponda con algún concepto, muy común en contextos de conocimiento muy específico y problema presente en todas las herramientas que consultan WordNet. En respuesta a esto se trabaja en dos variantes, una primera es hacer un mayor uso de las *palabras-enlaces* de dominios específicos y la segunda variante es hacer uso de la Base de Conocimiento que posee el Servidor de Mapas Conceptuales (SERVIMAP) en la cual se almacenan una gran cantidad de MC (Simón, 2006). Esos MC pueden ser utilizados para buscar proposiciones similares a la que se analiza y con esta nueva información hacer nuevas consultas en WordNet.

7 Trabajos Relacionados

En Gómez et al. (2004) se propone un mecanismo de transformación de un MC al lenguaje OWL. Se utiliza XTM como un lenguaje intermedio entre el MC y el OWL, relazándose de la siguiente forma: el MC se lleva a XTM, luego son aplicados un conjunto de reglas al XTM (Ej: (1) los conceptos expresados mediante *topic* en el XTM son expresados como *owl:Class rdf:...* en el OWL y (2) los tipos de relaciones expresadas en XTM como *association* son expresadas como *owl:ObjectProperty rdf:...*) y se obtiene el código OWL. Aquí se identificaron dos inconvenientes principales: (1) no se tiene en cuenta la semántica de la relación, todas las *associations* en XTM no siempre deben ser expresadas como propiedades en OWL; (2) el XTM es un lenguaje desprovisto de semántica en los elementos que expresan los tipos de relaciones del MC, por lo que mantienen en mismo problema presente en el MC de formalización del tipo de relación. En el caso de la propuesta de Hayes et al. (2004) se muestra un entorno de desarrollo colaborativo de ontologías basado en MC. Se parte de un RDF que es llevado a un MC, aprovechando la semejanza entre el *triples* de RDF (sujeto-predicado-objeto) y las *proposiciones* de los MC (concepto-enlace-concepto). La obtención del MC se realiza utilizando restricciones OWL para la depuración del RDF, *templates*, *estereotipos* para los *nodos* y un vocabulario restringido de p-e. Algunas diferencias identificadas: (1) se trabaja con documentos RDF y no OWL, (2) la representación del conocimiento en el MC mediante un vocabulario más restringido y menos natural para el hombre, (3) no se manifiesta una clara integración entre el lenguaje de ontologías y el MC.

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9 Conclusiones

Se obtuvieron las siguientes conclusiones en la investigación: (1) se demostró que existe una estrecha relación entre mapas conceptuales y ontologías; (2) la integración de mapas conceptuales (lenguaje visual) y OWL (lenguaje formal) crea las bases para el desarrollo de entornos de colaboración hombre-máquina en el trabajo con ontologías; (3) utilizar mecanismos complementarios de procesamiento de lenguaje natural para el análisis de mapas conceptuales permite lograr un nivel de interpretación semántica de sus relaciones muy útil para la formalización de estos en código OWL manteniendo la flexibilidad en su representación; (4) los procedimientos definidos garantizan una estrecha integración de mapas conceptuales con el código OWL en aquellos contextos en los que no se requiera de restricciones cuantificables, ni elementos de negación.

10 Referencias

Borst, P. (1997). *Construction of Engineering Ontologies for Knowledge Sharing and Reuse*. Ph. D. thesis, University of Twente, The Netherlands.

Cañas, A., Valerio, A., Lalinde, J., Carvalho, M. y Arguedas, M. (2003). *Using WordNet for Word Sense Disambiguation to Support Concept Map Construction.* Proc. of 10th International Symposium on String Processing and Information Retrieval. Ed. Springer-Verland. Manaus, Brasil.

Ceccaroni L. (2001). ONTOWEDSS - *An Ontology-Based Environmental Decision-Support Systems for the Management of Wastewater Treatment Plants*. Ph. D. thesis, Universidad Politécnica de Cataluña, Barcelona, España. pp. 14.

Ceccaroni, L., Willmott, S., Cortés García, U. y Barbera-Medina, W. (2005). @LIS TechNET: Hacia la enseñanza práctica de las tecnologías de Internet de la próxima generación. *Actas de la 5ª Conferencia Internacional de la Educación y la Formación basada en las Tecnologías (Online Educa Madrid 2005)*. Madrid, España. pp. 139-142 URL: http://docs.alis-technet.org/alis/pubs/technical-papers/alis-technet-proxima-generacion/

DARPA (2001). DAML+OIL ontology markup language. *Defense Advanced Research Projects Agency*. URL: http://www.daml.org/2001/03/daml+oil.daml

Farquhar, A., Fikes, R., Rice, J. (1995). The Ontolingua Server:a Tool for Collaborative Ontology Construction. URL: http://ksi.cpsc.ucalgary.ca/KAW/KAW96/farquhar/farquhar.htm

Fellbaum, Ch. (1998). *WordNet: An Electronic Lexical Database*, The MIT Press, University of Cambridge.

Gómez, H., Díaz B. y González, A. (2004). Two-layered approach to knowledge representation using conceptusl maps description logic, *Proc. of the First International Conference on Concept Mapping*. España.

Gruber, T. (1993) *Toward Principles for the Design of Ontologies used for Knowledge Sharing*. Formal Ontology in Conceptual Analysis and Knowledge representation. Guarino y Poli Ed., Kluwer Academic Publishers.

Hayes, P., Eskrindge, T., Reichherzer, T., Saavedra, R. (2004). A Framework for Constructing Web Ontologies using Concept Maps. *Proc. DALM Meeting.*

Magnini, B., Strapparava, C. y Glifio, *A.* (2002). *The Role of Domain Information in Word Sense Disambiguation*. Natural Language Engineering. Cambridge University Press. pp. 359–373.

Minsky, M. (1975). *A Framework for Representing Knowledge.* The Psychology of Computer Vision, McGraw-Hill, pp. 211-277.

Novak J. D. y Gowin, D. B. (1984). *Learning how to learn*, Cambridge Press. New York.

Pons-Porrada, A., Berlanga, R., Ruiz-Shulcloper, J. (2003). Un nuevo método de desambiguación del sentido de las palabras usando WordNet. *Proc. X Conferencia de la Asociación Española para la Inteligencia Artificial*. País Vasco.

The Protégé Project, *University of Stanford*, 2000, URL: http://protege.stanford.edu/

Smith, M., Welty, Ch., McGuinness, D. (2004). OWL Web Ontology Language Guide. *W3C*. URL: http://www.w3c.org/TR/owl-guide/

Simón, A., Willmott, S., Rosete, A., Ceccaroni, L. (2005). Modelo Unificado para la integración entre Ontologías y Mapas Conceptuales. *Reporte de Investigación*. Universidad Politécnica de Cataluña. LSI-05-64-R.

Simón, A. (2006). Plataforma para la Gestión del Conocimiento con Mapas Conceptuales. *Tesis de Maestría*. (Tutores: Rosete, A, Estrada, V.) Centro de Estudios de Ingeniería y Sistemas (CEIS). Instituto Superior Politécnico "José Antonio Echeverría" (Cujae), C. Habana, Cuba.

Studer, R., Benjamins, V. R., Fensel D. (1998). *Knowledge engineering: principles and methods*. Data and Knowledge Engineering, 25(1-2), 161–197.

Vossen P. (1997). EuroWordNet: a multilingual database for information retriveral. *Proc. DELOS Workshop on Cross-Language Information Retrieval*. Switzerland.

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MODELS OF SOCIAL CONSTRUCTIVISM, LABORATORY TEACHING AND CONCEPT MAPS TO BUILD SCIENTIFIC KNOWLEDGE AND ORGANIZE CONCEPT NETWORK

TEACHING EXPERIENCES IN FIRST LEVEL EDUCATION IN ITALIAN SCHOOLS

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Abstract. Through the various experiences described by a group of teachers involved in an innovative project about science teaching, this paper aims to show how some students, 6- 13 year olds, when given the opportunity to live and operate in a particularly stimulating and significant learning environment, are able to gain knowledge via constructive processes. While social constructivism provides reference guidelines in educational-teaching practices, concept maps are a tool used to promote, organize and synthesize acquired knowledge, while meditating on thinking operations. Teaching action is situated in significant operative contexts, in which students are driven to ask questions, make hypotheses, analyze facts, make connections, verify ideas, and create concepts. A science laboratory is a cognitive space where answers can be found to multiple questions and issues derived from observation of scientific phenomena. Teachers are aware that knowledge is not transmitted, it is built by students. Knowledge building is not a lonely, individual operation, it is a process created by sharing experiences and discovering meanings together with peers and teachers. Concept maps accompany all stages of knowledge building and are an effective teaching instrument to strengthen cognitive and metacognitive strategies, helping students to build a structured, significant knowledge network.

1 Overview

This paper is the result of analyses and reflections on strategies and methods used in teaching practices by a group of Italian primary school teachers (6-11 year old students) who have been involved for a few years in an innovative project in the field of science teaching. Some classes of junior high school participated in the project (11-14 years old). The title of the project is " The words of science". The teachers involved in the project are: Baldoni M.O Berionni A., Borioni A., Ceccotti G., Cimetta M.L., Giardina F., Liviabella I., Lorenzetti F., Morettini C., Moscatelli A.M., Passeri S., Pastuglia R., Pavoni L., Ranaldi G., Rossi G., Valloscuro M., and Zamponi D.

The project is based on systematic use of concept maps and laboratory teaching. Maps and laboratory teaching give 6-12 year students the opportunity to operate in a particularly stimulating learning environment that creates the necessary conditions for personal knowledge building.

Students are players and protagonists during teaching activities through a continuous process of discovery, investigation, research and synthesis. Students attempt to give answers to multiple questions arising from the observation of scientific phenomena or from the solution of problematic issues. In this context, the building of concept maps allows students to become aware of their knowledge building processes whilst also representing the knowledge synthesis operated by students.

2 Science laboratory and learning environment

Science laboratory activities are structured around the search for coherent and correct answers to questions aroused in students through random or programmed observation.

The questions asked spontaneously by students are not "basically different" from those that guide and urge investigations, discoveries and definition of scientific theories. Evidently, in view of the very young age of the students, questions arise from within a context of factual experiences where real knowledge may still coexist with misconceptions and fantasy.

Science teaching with a laboratory teaching method orientates the search for answers and coherent and correct explanations through learning processes in which students work and interact to gain the new knowledge that will allow them to read the cause of scientific phenomena or the explanation of observed situations.

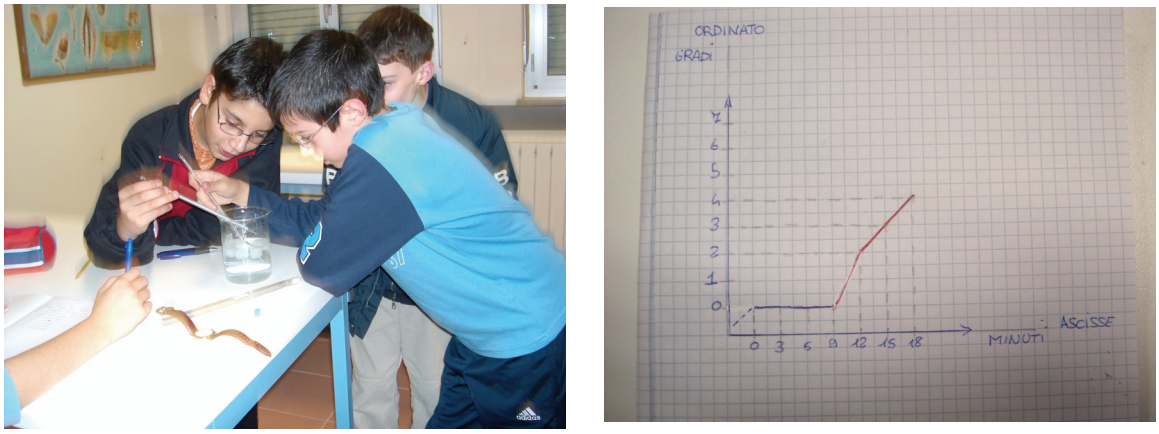


Figure 1. Junior High School first-grade students (11 years old) ask questions, make hypotheses and verify them to calculate latent heat of fusion.

In this teaching practice students and teachers play well-defined roles, that is to say invert the direction of traditional transmissive teaching, creating a learning-teaching process in which the student is given a central role as protagonist and the teacher a second-level role as organizer, guide and facilitator of teaching processes.

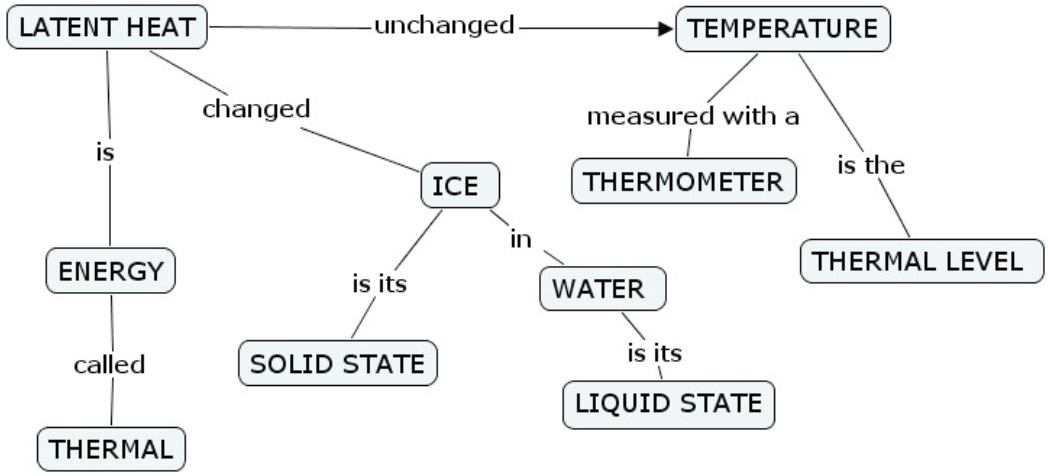


Figure 2. Concept map built by students to express the knowledge acquired during laboratory teaching session.

2.1 Designing the learning environment

Designing a science laboratory means to elaborate teaching practice and teaching role in a constructivist approach in which knowledge gained by students is an active process. The teacher prepares and organizes materials, procedures and relevant contexts to urge and guide self-learning processes.

With his/her expert map, the teacher defines:

- the knowledge field to promote
- the aspects to investigate
- the knowledge synthesis at which the students should arrive.

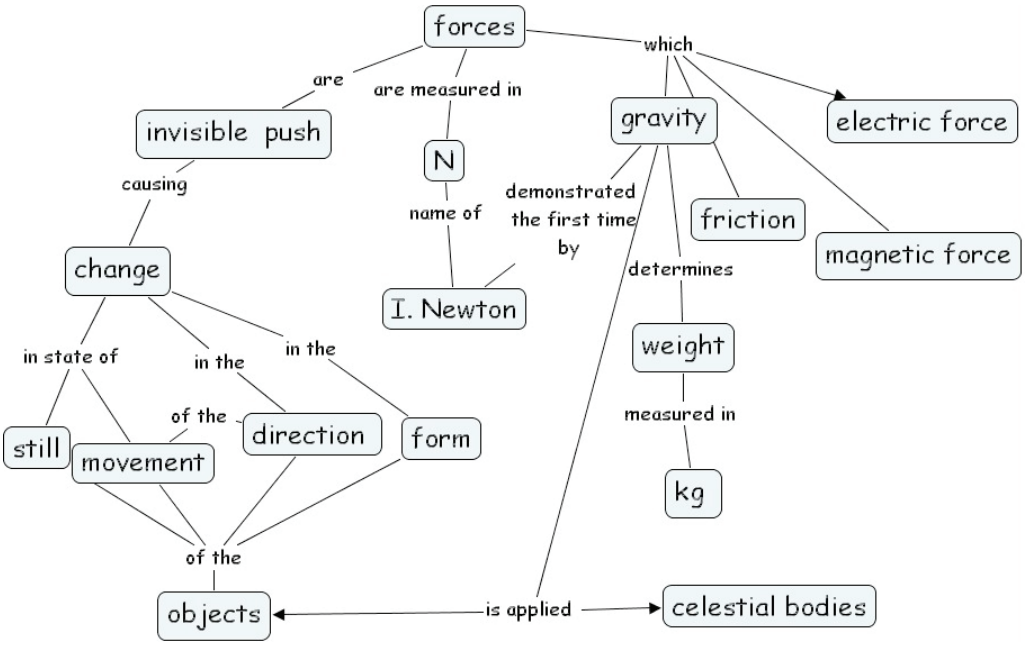


Figure 3. Programming map of a large teaching unit on forces in fifth-grade primary students (10-11 years).

Once activities start, the class of students becomes the protagonist and each student is the main actor in a knowledge process that generates significant learning whenever students structure, integrate and reconfigure their previous knowledge. The teacher recedes from the foreground and only provides inputs, stimuli, suggestions to strengthen and direct the thinking procedures and strategies activated by the students.

2.2 *Promoting and addressing knowledge processes*

Receding from the foreground means for the teacher to avoid giving explanations, examples and direct answers, whilst guiding students towards active processes, such as analysis, observation, comparison, and the search for alternative routes in problem-solving.

Knowledge is considered an active, unique and personal process for each student through interaction and social cooperation with the other students of the class in a perspective that refers to social constructivism paradigms (Varisco 2004). Consequently, the teaching activity is expressed according to three guidelines:

- to address the students' action towards multiple routes, searching for logical, coherent solutions and explanations, solicited and anchored with a concrete context;
- to promote collaboration, discussion, mediation, negotiation with the other students;
- to use language and c-maps as tools for reflection, reasoning, analysis and synthesis.



Figure 4. 6-7 year old students make laboratory experiences to understand seeds. They build the first c-maps divided into small groups with 3-4 students in each.

The science laboratory becomes the learning environment where students work together, helping each other, and learning how to search for and use tools and resources in problem solving situations. The teacher facilitates, encourages, promotes activities in which students interact, design, express and discuss solutions, ideas and theories.

2.3 The role of language

In the different phases of teaching activities, verbal communication and conversation among students are used to clarify thinking processes, express doubts, highlight intuitions, logical connections, including doubts, perplexities, misunderstandings, incoherent associations, errors.

Language and thought express themselves and get enriched with new elements in a circular relation of mutual influence (Piaget 1979). Students build disciplinary micro-languages that are well structured and anchored in the processes of significant learning. The teacher records significant interventions, stimulates conversation, collects and directs coherent interventions, promotes reflection, and stimulates students to search for other elements to confirm or refuse the hypotheses made.

Through dialogue students mediate their knowledge with the group and activate efficacious strategies to achieve the new knowledge, operating in what Vygotskij (1980) defines as *proximal development zone*. The laboratory creates the cognitive space in which new tasks and knowledge can be faced through communicative and social relations with peers and teacher.

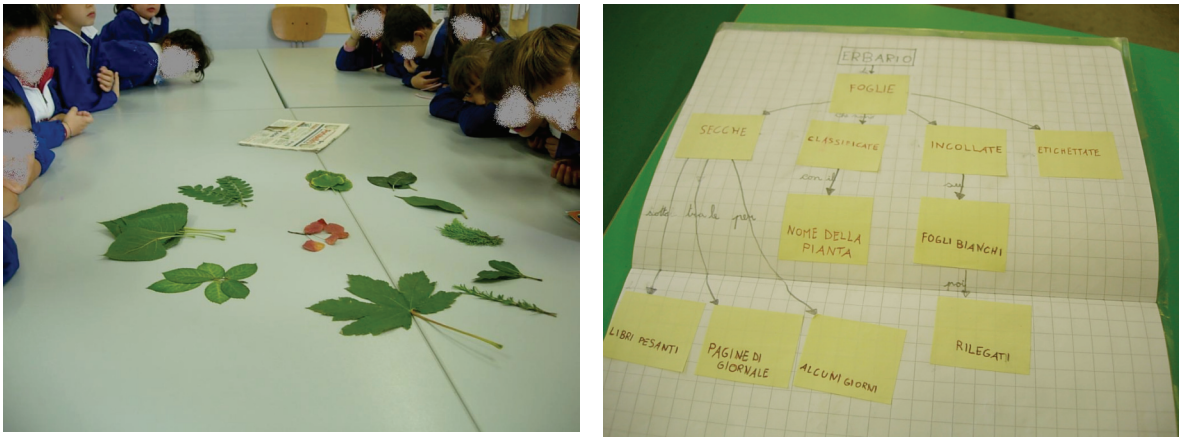


Figure 5. Through language and guided conversation 7-year old students elaborate the experiences made when making a herbarium and synthesize them with a c-map.

2.4 Building a concept map

In these teaching practices concept maps are the most significant process and are systematically used by the students to express and synthesize the knowledge they have acquired. Students operate individually using the concepts identified through the communicative-cognitive mediation operated with peers. The result is maps that show the knowledge that the learning context has produced in each student. Each map therefore allows the teacher to evaluate the learning process.

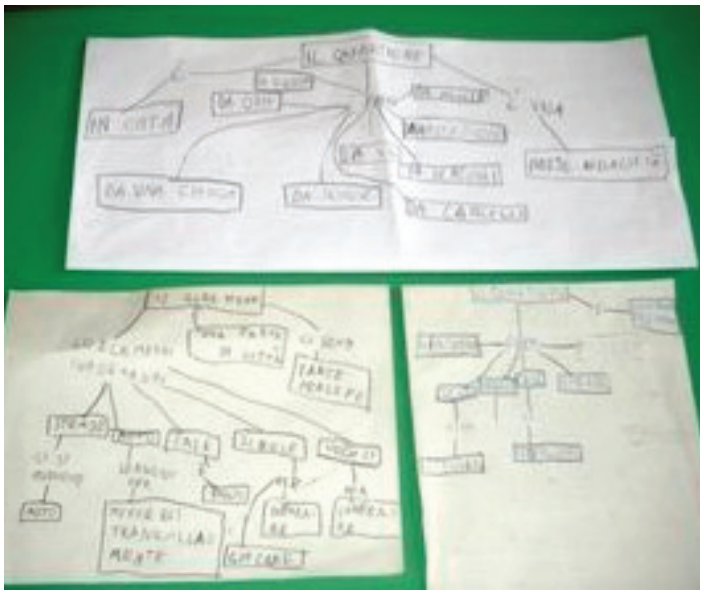


Figure 6. The maps individually prepared by third-grade primary school students (8-9 years) show that each student has activated personal learning processes and structured new knowledge in a personal way.

Likewise, emerge weak, poorly thought out structures from students who have structured on incomplete cognitive synthesis presenting misconceptions and errors. In these situations, maps make the teacher aware of specific educational needs of some students. The teacher does not correct errors directly but guides students towards self-correction through a series of inputs. Also in these cases mediation and interaction with peers is extremely effective, especially when students share and discuss individual maps to work an additional synthesis before building the group map.



Figure 7. (Third-graders /8-9 years). The group map is created on a large table with sheets and labels that can be moved and modified. This allows students to work in group in a functional, constructive way.

The abilities of each student come into play through dialogue and collaborative interaction. Each diversity of thinking is an opportunity for personal enrichment and growth. The building of the group map provides an additional opportunity for reflection and realization of meanings, including them in a reticular structure that is a social and shared construction of knowledge. Another strategy used by the teacher is to give students a map structure with some concepts, while other concepts must be added by the students. In other situations the students work on maps with concepts only and must include links, or vice versa.

Being a tool for knowledge, concept maps accompany students along their entire school career. They start building maps in first grade of primary school (6 years old). The map allows students to represent their knowledge through a reticular structure, which uses a limited number of elements and rules, which are easy to acquire and use.

The first maps are built playfully in large spaces. Concepts are represented by objects or drawings. Connections are described and explained. In this way students structure meanings and at the same time learn the "syntax" of the map, becoming aware of space and meanings that labels, arrows, concept-words, and links have in it.





Figure 8. 6-year old students building the first concept maps.

Secondly students realize that c-maps can be used to "tell" their knowledge. The building of the map becomes a dynamic process, by moving, deleting, and integrating elements on paper. Pencils, erasers, post-it notes are the working tools.

The use of CmapTools (Cañas et al. 2004) software allows students to fully experiment the potential of concept maps, such as their capacity of being reticular, dynamic and adaptable to thought processes.



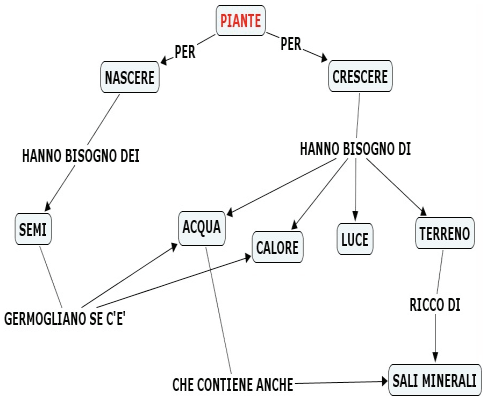


Figure 9. Group maps built by 8-year old students.

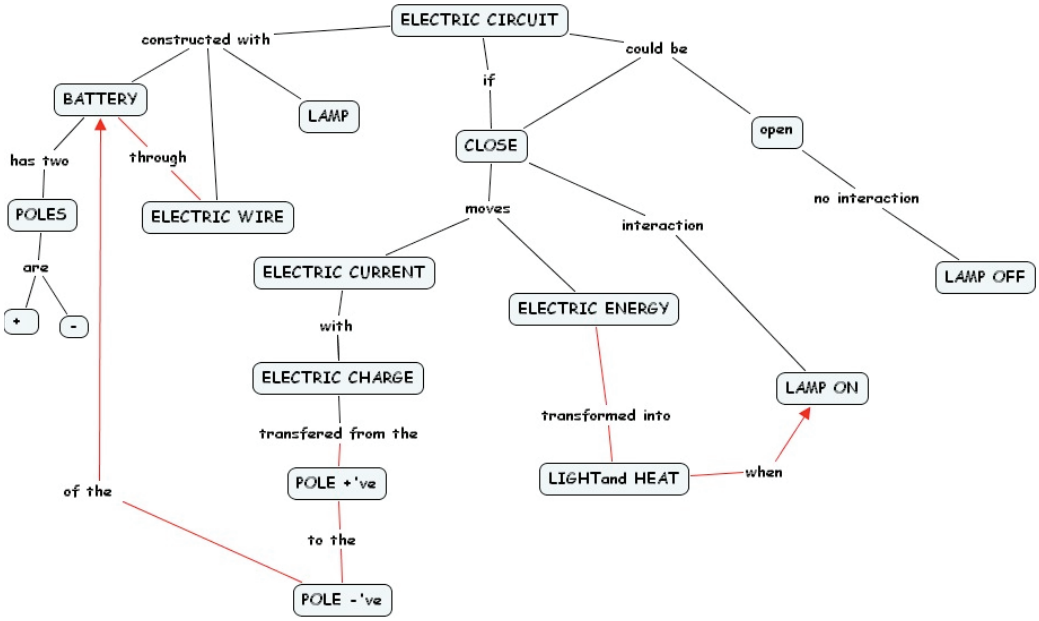


Figure 10. Group map built by 10-year old students.

Although the early use of concept maps creates the ideal conditions to promote significant learning, nevertheless students can familiarize with this metacognitive instrument at any time along their educational process.

This year teachers from a junior high school have joined the teaching innovation project for science teaching and a first group of 16 students from first and second junior high grade (11 - 13 years old) are using concept maps in the science laboratory for the first time. A second group of 28 students uses concept maps as a tool to acquire or strengthen their studying method. In spite of being a very recent initiative (3 months), significant aspects have been identified for analysis and reflection. Students and teachers using and experimenting this metacognitive tool for the first time, can therefore understand how this system helps them to organize and structure meanings and knowledge.

The potential of maps and CmapTools becomes clear when maps are used, contextualized, and represent a knowledge field or space. At first, some problems may appear if the said field refers to a large topic, because students are not used to structuring knowledge in a reticular configuration through submaps and are not able to introduce everything they want only one map. Once students are guided to organize a map outline, showing the plot to generate other connected maps, the work will continue without any problems and students will discover that maps can help them to reflect, organize and synthesize the knowledge they have acquired. Using the maps becomes an effective means for all students, regardless of the skills they have already acquired, because they stimulate metacognitive reflection processes and contribute to make a structured synthesis of any educational topic. Maps give each student, including students with difficulties, an additional instrument towards significant learning.

3 Summary

The teaching experiences described in this paper have proved especially effective since they are guided by an educational and training model that privileges laboratory discovery and problem-solving processes and procedures in a cooperative group.

In this context concept maps support and substantiate the different steps faced by students to build meanings and knowledge. They become a method and a strategy to promote significant learning, combining the leading role of the single students (individual map) with the group cooperative mediation (group map). Moreover, the maps play a relevant role in the acquisition of metacognitive competences, because they induce reflection and thought , through a reticular structure, on the knowledge that students have acquired or assume to have acquired.

Thinking, reflecting, representing a knowledge "space" through maps, means to test a personal knowledge experience, which is likewise mediated and enriched through dialogue and interpersonal-social communication.

References

Novak, J. D. L'apprendimento significativo. Le mappe concettuali per creare e usare la conoscenza, tr. it. Erickson, Trento 2001.

Novak, J. D., & Gowin,. Imparando ad imparare tr. it.,Sei Torino 1984.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Oldfather P., West J.; White J., Wilmarth J., L'appredimento dalla parte degli alumni. Didattica costruttivista e desiderio di imparare, tr. it.. Erickson, Trento 2001.

Piaget J., Il linguaggio e il pensiero del fanciullo, tr. it. Giunti, Firenze 1968.

Piaget J., La costruzione del reale nel bambino, tr. it. La Nuova Italia, Firenze 1979.

Polito M., Attivare le risorse del gruppo classe. Nuove strategie per l'apprendimento reciproco e la crescita personale, Trento, Erickson, 2001.

Varisco B.M., Costruttivismo socio- culturale. Genesi filosofiche, sviluppi psico-pedagogici, applicazioni didattiche, Carocci, Roma 2004.

Vygotskij L.S., Il processo cognitivo, tr. it. Boringhieri, Torino 1980.

Vygotskij L.S., Pensiero e linguaggio, tr. it.,Laterza Bari 1992.

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NATUREGATE®, CONCEPT MAPPING AND CMAPTOOLS: CREATING GLOBAL NETWORKS OF SERVERS FOR IMPROVED LEARNING ABOUT, IN AND FOR NATURE, ECOSYSTEMS, BIODIVERSITY, AND SUSTAINABLE DEVELOPMENT

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Abstract. NatureGate® innovation is described and analyzed using concept maps and CmapTools. First, it is shown, that there are new kind of free services like Google, which however create plenty of added values for individuals, societies and the whole humankind. At the same time they produce sustainable profits also to the original founders and keepers of those services. NatureGate® could be that kind of service. Both individuals and societies need knowledge about their organisms and ecosystems. CmapTools could be integrated with all the servers. It could be used for both individual and social knowledge construction, and knowledge management. NatureGate® is R&D project, which is planned to become a global free service in the WWW. The servers have to be powerful and fast, like those of Google. The vision is create kind of "NatureGoogle". Research and development is needed in order to keep the project in leading edge, and for continual quality assurance and improvement, and innovations. NatureGate® promotes e-learning for sustainable development both by alone and together with CmapTools, another free of charge, and empowering innovation. UN decade of Education for sustainable development is described as one of the most important motivators and contexts of NatureGate® and CmapTools. However, both tools can be used to promote e-learning, also without any reference to values of sustainable development. CmapTools is presented in relation to NatureGate® innovation and e-learning.

1 Introduction

NatureGate® is designed to be a digital and e-learning gate into experiential, meaningful, deep, innovative, empowering learning, and search about, in and for Nature, natural sciences, biodiversity and sustainable development. E.g. many people come to Costa Rica because of its beautiful nature. Costa Rica is one of the 34 global biodiversity hotspots. Concrete starting points for NatureGate® anywhere in the World, will be photographs and videos of local flowering plants (Angiosperms). Probably most people are fascinated and motivated by them. Human beings are part of biosphere, and very probably most of us have strong sense and feeling of biophilia (e.g. Wilson 1984, Kellert & Wilson (Eds.) 1993). Big, aesthetically appealing, professionally created high quality photographs of flowering plants probably motivate people to learn more about them, their biotopes, ecosystems, biodiversity, environmental issues, and finally integrating ecologically, economically and socially sustainable development. These are hypotheses to be tested in later empirical studies. The first NatureGate® server is under construction in Finland in July - August 2006. University of Helsinki gave 50 000 euros for creating a prototype.

There are promises that it will be financially self-supporting in long term, in the same way as Google® is. Google has shown amazing development from 2000 to 2006 (Battelle 2005, Vise & Malseed 2005). It has become from humble beginning to one of the biggest and most valuable companies in the world. Google and its rivals have transformed both business and the whole culture by the web search-activities that they created. The idea of NatureGate® is like "NatureGoogle", a free service, which however creates plenty of added values and business opportunities for everybody, both individuals, societies, and organizations, for the whole humankind. The concept of NatureGate is trademarked and registered, and it uses patented fast digital software to identify plants, animal, other organisms or practically any objects. Nobody can legally steal the idea. Also the time and expertise to create sufficiently high quality photographs is very demanding. It takes about a decade to become an expert in any field. The partners of NatureGate® have enough expertise needed in order to be at the leading edge in this nature R&D business.

NatureGate® will use the best available information and communication technology. NatureGate® can be designed to be (1) in one local computer, (2) in a local network or (3) preferably in the Internet, in the WWW, or any of its future forms. E-learning is always involved. Because NatureGate® uses both pictures and verbal descriptions of flowering plants, and ecosystems, and models of sustainable development, also multimedia learning is involved (Mayer 2001 and 2003). Sustainable development is very complex, and difficult problem. It will demand plenty of social learning, including collaborative knowledge building. CmapTools as described by Cañas & al. (2004) will be used with NatureGate® for that purpose. The preferred version of concept mapping will be the one based on Novak and Gowin (1984), Novak 1998 and adapted by Åhlberg (1993, 2004a and 2004b). CmapTools can

promote all aspects of high quality learning from meaningful learning to collaborative knowledge building as described by Åhlberg (2006).
NatureGate® can be used also to promote public-generated multimedia by the material that public themselves upload to it and by arrangements and rearrangements of all selected material, and creative use of artistic tools like CmapTools and other software available.

2 NatureGate® and UN Decade of Sustainable Development (2005 2014)

UN is an organization representing all countries. In this sense it represents humankind better than any other organization. UN has declared years 2005 – 2014 as Decade of Education for Sustainable Development. In this article we will discuss possibilities of how to best promote this decade by e-learning. According to international UN agreements, Sustainable development ought to be promoted by all countries, all sectors of societies, government, and education included, from Kindergarten to university teaching and research. UNESCO coordinates the UN Decade of Education for Sustainable Development: http://portal.unesco.org/education/en/ev.php-URL_ID=27234&URL_DO=DO_TOPIC&URL_SECTION=201.html .

United nation University and in particular its Institute of Advance Studies (UNU IAS) is an important organization in planning how to best promote globally sustainable development. It has presented an idea of Regional Centres of Expertise (RCE) on Education for Sustainable Development, http://www.ias.unu.edu/binaries2/EfSD/RCE%20general.pdf. This document defines RCEs as "a network of existing, formal, nonformal and informal education organisations, mobilised to deliver ESD to local and regional communities. A network of RCEs worldwide will constitute the Global learning Space for Sustainable Development." What is not said is how these networks and centres are supposed to be communicating. It may be self-evident that through Internet. The other point that is disturbing is the idea that these centres ought to somehow "to deliver (sic!) ESD to local and regional communities". It is everyday thinking that experts deliver lectures to lay people. Problems of sustainable development are so complex that far better idea is collaborative knowledge building (e.g. Åhlberg & al. 2001, Åhlberg, Äänismaa & Dillon 2005, Bereiter 2002, Scardamalia & Bereiter 2003, Scardamalia & Bereiter 2006).

'Sustainable Development" has three "pillars" or aspects: ecological, economical and social. These aspects have to be continually integrated in education for sustainable development according to international agreements, e.g . Johannesburg World Summit 2002 (United Nations 2002). Most people do not understand abstract language and complex problems of sustainable development. NatureGate® is an innovation to facilitate learning and thinking about, in and for sustainable development from concrete photographs of local flowers, to ecosystems of which they are part to larger global ecosystems and finally to combined biosphere including human economic and social activities (Åhlberg, Lehmuskallio & Lehmuskallio 2006). While using (becoming) NatureGate® services, people could stay as long as they prefer in the state of enjoying impressive, both exiting and relaxing, beautiful, accurate photographs and videos of flowers. However, they'll have in their use also patented digital software for fast, easy and reliable identification of local flowers, other plants, and organisms, and their ecosystems, up to level of biosphere.

3 Integrating NatureGate® and CmapTools servers to create real Global Learning Space for Sustainable Development

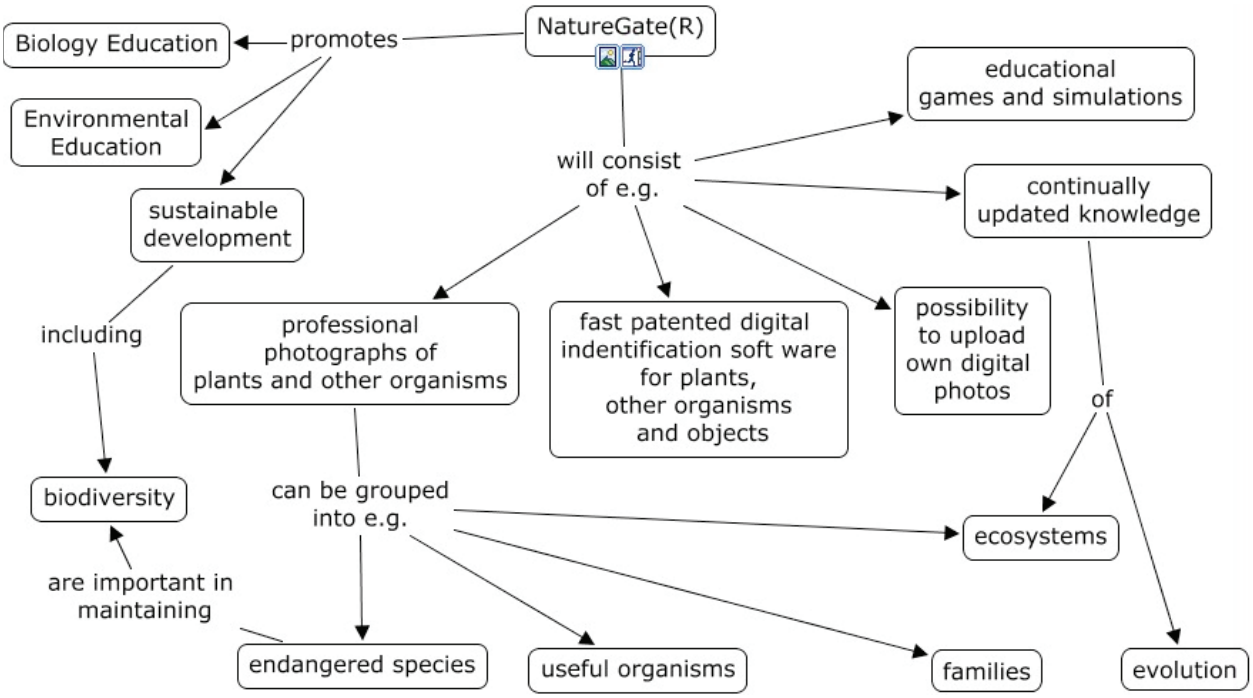


Figure 1. Main characteristics of NatureGate®. Presented as a concept map created by CmapTools software.

4 Acknowledgements

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5 References

Åhlberg, M. 1993. Concept maps, Vee diagrams and Rhetorical Argumentation (RA) Analysis: Three educational theory-based tools to facilitate meaningful learning. Paper presented at The Third International Seminar on Misconceptions in Science and Mathematics. August 1- 5, 1993. Cornell University. Published digitally in the Proceedings of the Seminar, http://www.mlrg.org/proc3abstracts.html (Read 12. 6. 2006) The whole paper:

http://www.helsinki.fi/sokla/bgee/Ahlberg_Cornell_1993.doc

Åhlberg, M. 2004a.Varieties of concept mapping. In Cañas, A., Novak, J., Gonzales, F. (Eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept mapping. CMC 2004. Pamplona, Spain, Sept 14 – 17, Vol. 2, 25- 28, http://cmc.ihmc.us/papers/cmc2004-206.pdf

Åhlberg, M. 2004b. Concept mapping for sustainable development. In Cañas, A., Novak, J., Gonzales, F. (Eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept mapping. CMC 2004. Pamplona, Spain, Sept 14 – 17, Vol. 1, 39 – 44, http://cmc.ihmc.us/papers/cmc2004-233.pdf .

Åhlberg, M. 2006. A new theory of high quality learning to enhance education and learning for sustainable development. A paper accepted to be published in the Proceedings of The Third World Environmental Education Congress, October 2 – 6, 2005, Torino, Italy.

Åhlberg, M., Äänismaa, P. & Dillon, P. 2005. Education for sustainable living: Integrating theory, practice, design and development. Scandinavian Journal of Educational Research 49(2), 167 - 186.

Åhlberg, M., Kaasinen, A., Kaivola, T. & Houtsonen, L. 2001. Collaborative knowledge building to promote in-service teacher training in environmental education. Journal of Information Technology for Teacher Education 10(3), 227 – 238.

Åhlberg, M., Lehmuskallio, E. and Lehmuskallio, J. 2006. E-learning using NatureGate® and CmapTools to promote Nature, natural sciences, biodiversity and UN Decade of Education for Sustainable Development (2005 – 2014). A presentation accepted for E-Learn 2006: World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education. October 13-17, 2006. Honolulu, Hawaii.

Battelle, J. 2005. The search. How Google and its rivals rewrote the rules of business and transformed our culture. Boston: Nicholas Brealey Publishing.

Bereiter, C. 2002. Education and Mind in the Knowledge Age. London: Lawrence Erlbaum.

Cañas, A. J. et al. 2004. CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.) Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra, Vol. 1, 125-133.

Kellert, S. & Wilson, E. (Eds.) 1993. The biophilia hypothesis. Washington, D.C.: Island Press.

Novak, J. 1998. Learning, creating and using knowledge. Concept Maps ™ as facilitative tools in schools and corporations. London: Lawrence Erlbaum.

Novak; J. & Gowin, B. 1984. Learning how to learn. Cambridge: Cambridge University Press.

Scardamalia, M. & Bereiter, C. 2003. Knowledge building. In Guthrie, J. (Ed.) Encyclopedia of Education. New York: Macmillan Reference, 1370 – 1373.

Scardamalia, M. & Bereiter, C. (2006) Knowledge building: theory, pedagogy, and technology. In K. Sawyer (Ed.) The Cambridge Handbook of the Learning Sciences. Cambridge: Cambridge University Press, 97 – 117.

United Nations. 2002. Report of the World Summit on Sustainable Development. Johannesburg, South Africa, 26 August - 4 September. A/CONF.199/20, http://daccessdds.un.org/doc/UNDOC/GEN/N02/636/93/PDF/N0263693.pdf?OpenElement

Vise, D. & Malseed, M. 2005. The Google story. New York: Bantam Dell.

Wilson, E. 1984. Biophilia. Cambridge, MA: Harvard University Press.

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ORIGEN Y DESTINO DEL MAPA CONCEPTUAL. APUNTES PARA UNA TEORÍA DEL MAPA CONCEPTUAL

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Abstract. El mapa conceptual tuvo su origen en el contexto de una investigación psicoeducativa a largo plazo dirigida por Joseph Novak. Inventado en 1972 la primera función del mapa conceptual fue la *técnica para el análisis de entrevistas*. En el progreso de la investigación se diversificaron sus funciones constituyendo a la *técnica* como una *herramienta* para la investigación y la transformación de la práctica docente, la investigación educativa y la psicológica. La difusión y adaptación de la herramienta a distintos contextos ha constituido un nuevo objeto de interés dando lugar a nuevos hechos educativos y su problematización tanto en el marco teórico original como en otras nuevas aproximaciones teóricas y disciplinarias. El trabajo que aquí se presenta analiza el origen y la transformación del mapa conceptual para comprender las prácticas educativas y de investigación actuales en torno a la herramienta, se intenta entender al mapa conceptual como un *objeto de estudio*, esto resulta relevante para una comunidad académica y de investigación que con sus prácticas genera la necesidad de plantear una *teoría del mapa conceptual.*

1 El mapa conceptual en expansión

Novak (2004) ha descrito de manera sintética la invención del mapa conceptual, las transformaciones y funciones que esta técnica adquirió y cómo modificó las formas de indagación y análisis en la investigación psicológica y educativa. Originado en el contexto de una investigación de largo plazo, (Novak, 1998b, 2004; Novak y Musonda, 1991), el mapa conceptual fue inventado para responder a problemáticas metodológicas, teóricas y técnicas de la propia investigación.

Comprender el origen y las transformaciones de la herramienta permite entender de manera más compleja la *técnica*, la *teoría*, la *metodología* y los *usos educativos* del mapa conceptual. La técnica se ha expandido mundialmente y es utilizada en una gran diversidad de prácticas educativas y de investigación dando origen a un nuevo objeto teórico y de prácticas que da lugar a plantear una *teoría del mapa conceptual* (Aguilar Tamayo, 2005).

Actualmente el *mapa conceptual* es un *concepto* y una *práctica* que implica a comunidades educativas y de investigación cuya diversidad plantea alejamientos, distorsiones, acercamientos y/o innovaciones, de manera implícita o explícita, con los fundamentos teóricos y metodológicos que le dieron origen. El mapa conceptual se ha constituido en un *instrumento de enseñanza e investigación* pero también en un objeto mismo de investigación. Los temas y problemas reunidos entorno al *mapa conceptual* son diversos y pueden sugerir aproximaciones desde distintas disciplinas y teorías, aunque resulta una referencia común la teoría del aprendizaje significativo, esta no es suficiente para explicar las prácticas alrededor el mapa conceptual, la atención sobre *el* mapa conceptual ha cambiado las coordenadas teóricas y metodológicas, el mapa conceptual se expande a prácticas y teorías no consideradas en un primer momento, es por ello necesario reconstruirlo conceptualmente para enfrentar el análisis de nuevos fenómenos educativos.

2 El *big bang* del mapa conceptual

Novak (1998a) ubica la invención y utilización del *mapa conceptual* en el año de 1972 (p.30), en el contexto de un proyecto de investigación (Novak y Musonda, 1991) que planteó al equipo de investigadores problemáticas técnico-metodológicas, además de las teóricas. El desarrollo de la técnica y su uso regular en las prácticas de investigación se dio a partir de año 1974, inaugurando además su aplicación didáctica (Novak, 1998a, p.75).

Las funciones que pueden distinguirse del mapa conceptual varían de acuerdo al nivel de análisis, Novak (1998b, p.14) ha descrito la técnica y su origen de distintas formas, una de ellas menciona que la técnica surge como una *herramienta y método* permitiendo "representar las estructuras cognitivas y sus cambios en los niños" en estudio (p.14). La *herramienta y el método* son dos niveles funcionales del mapa conceptual cuya distinción es analítica puesto que en el proceso de investigación las funciones que adquirió el mapa conceptual fueron resultado mismo del proceso de desarrollo de la herramienta y de su adaptación a nuevas situaciones investigativas.

La primera función del mapa conceptual surge de una necesidad particular del proceso de análisis de entrevistas realizadas a los sujetos en estudio (Novak, 1998a, p.135; 1998b, p.15; Novak y Musonda, 1991) y para indagar acerca de las *estructuras cognitivas* (Novak, 1998a, p.48). La interpretación y análisis de las entrevistas consistía en el reconocimiento de aquellas proposiciones de conocimiento enunciadas por el niño (Novak y Musonda, 1991, p.126). La metodología de elaboración y comparación del mapa conceptual permitió constituirlo y reconocerlo como un *sistema de representación* válido *de la estructura cognitiva* del sujeto (Novak y Musonda, 1991, p.134). Aunque estas funciones, y otras más que serán comentadas, se traslapan, no tienen el mismo propósito ni se originan en las mismas necesidades.

La *herramienta* del mapa conceptual es, en su origen, una *técnica de investigación* para el análisis de datos recogidos en las entrevistas, la idea y su desarrollo se da en estrecha relación con la teoría de Ausubel (2002) ya que la herramienta es una instrumento para *el análisis* desde el marco conceptual que ofrece la teoría del aprendizaje significativo, es por ello que el análisis se basa en el reconocimiento de la *palabra-concepto* y la *proposición* (Novak, 1998a, p.48). El análisis genera un *producto* que es el propio mapa conceptual que *representa,* de acuerdo a la interpretación basada en la teoría del aprendizaje de Ausubel, los conocimientos previos y los recien adquiridos (Novak, 1998a, p.48) de los alumnos en relación al proceso de instrucción efectuado durante el desarrollo del proyecto de investigación (Novak y Musonda, 1991). La elaboración del mapa conceptual inicia como una *transformación de los registros* y produce una *representación* interpretable desde una determinada teoría, así el mapa conceptual producido cambia su función para ser una *representación* válida que permite conocer acerca *de la estructura cognitiva de los sujetos*. Tanto la entrevista transcrita y el mapa conceptual son *representaciones,* resultando más adecuada para los fines de la investigación, la representación tipo mapa conceptual puesto que posee un valor agregado que es la representación explícita y jerárquica de las relaciones conceptuales y proposiciones.

Las características iniciales del *mapa conceptual,* surgidas de la necesidad de una *técnica para análisis,* se transformaron rápidamente y la herramienta adquirió nuevas funciones. Más allá del análisis de datos, el mapa conceptual funcionó luego como instrumento para la recolección y generación de los datos de la investigación, un ejemplo de esto último el el uso del mapa conceptual para la *planeación de la entrevista* y no sólo para la trascripción y/o análisis de esta (Novak, 1998a, p.135).

La adquisición de nuevas funciones del mapa conceptual se dio de manera dinámica y según al progreso de la investigación. De acuerdo a las fechas aproximadas que da Novak, en 1972 se inventa la técnica, y para 1974 pasa de ser una técnica de análisis de datos a cumplir funciones como estrategia metodológica, modelo de estimulación experimental (ya que son los propios sujetos en estudio quienes los elaboran) y *herramienta para el aprendizaje,* incluso para los mismos investigadores ya que la elaboración de mapas conceptuales son parte del proceso de comprensión de la teoría de Ausubel (Novak, 1998a, p.75). Curiosamente no existe una referencia explícita hacia el mapa conceptual en la obra que publicó Novak en 1977, *A Theory of Education*, aunque si hace mención sobre la utilidad de los esquemas y diagramas para facilitar la comprensión de las relaciones conceptuales implicadas en una teoría (Novak, 1982, p.68). Varios de los esquemas presentados en este texto (versión consultada en español, Novak, 1982) presentan características técnicas relacionadas al mapa conceptual, en varios momentos muestran relaciones entre conceptos acompañadas por las palabras enlace, creando la unidad semántica y proposicional que distinguen al mapa conceptual (Novak y Gowin, 1988)

La rápida adquisición de funciones del mapa conceptual lo constituyeron como una *herramienta para observar eventos y objetos* (Novak, 2004, p.461) lo que origina una aproximación metodológica distinta al evento y cómo éste es observado. Considerado así, el mapa conceptual es producto y productor de una nueva forma de investigación psicológica y educativa, la propia teoría de Ausubel (2002) era ya una ruptura con los paradigmas teóricos y experimentales de la época dominada por el conductismo (Novak, 1982, 1998a; Novak y Gowin, 1988), el mapa conceptual es en ese sentido, parte de un proceso de renovación paradigmática que busca construir objetos de investigación en el campo psicológico y educativo y además para transformación de la práctica educativa (Novak, 1982; Novak y Musonda, 1991).

La reconstrucción que se ha hecho sirve para comprender que la presentación del mapa conceptual a la comunidad educativa se hace cuando la técnica tiene varios años de estabilidad y práctica y privilegiando ciertas funciones de la herramienta. Las referencias que Novak y Gowin (1988) hacen en el primer libro que trata de manera específica la técnica del mapa conceptual, destacan como antecedentes bibliográficos 4 trabajos realizados o publicados entre 1981 y 1983 mientras que la técnica cumplía funciones didácticas y para el aprendizaje desde 1974.

En *Learning How to Learn* (Novak y Gowin, 1984)*, Aprendiendo a aprender*, versión en español (1988), se presentan dos técnicas; el mapa conceptual y el diagrama UVE. Este texto es dirigido principalmente a los educadores y a los aprendices, poniendo interés en brindar "ejemplos de estrategias sencillas, pero poderosas en potencia, para ayudar a los estudiantes a aprender y para ayudar a los educadores a organizar los materiales objeto de este aprendizaje" (Novak y Gowin, 1988, p.19). Aunque el énfasis se pone en la enseñaza y aprendizaje, Novak y Gowin (1988) recuperan, en el último capítulo de la obra, las funciones del mapa conceptual y UVE como herramientas para la investigación, aunque el discurso se dirige fundamentalmente a la formación de investigadores más que a una discusión centrada aspectos metodológicos, que son referidos pero no desarrollados, probablemente debido a los propósitos mismos de la obra y a que la discusión se había presentado en otro momento (Novak, 1982).

Actualmente los usos y aplicaciones del mapa conceptual se han diversificado, Kommers y Lanzing (1998) refieren a un estudio de Shavelson, Lang y Lewin (1994) en cual se encontraron 128 variaciones en la técnica de elaboración de mapas conceptuales. Cañas junto con otros investigadores (Coffey et al., 2003) han descrito más de 32 formas y/o aplicaciones, cada una con sus variantes y algunas otras fuera del campo educativo, por ejemplo, aplicaciones en la inteligencia artificial o análisis organizacional, esto resulta interesante pues muestra que la adquisición de nuevas funciones y prácticas han trascendido el énfasis educativo presentado originalmente en Novak y Gowin (1988). Varias de las innovaciones en el uso del mapa conceptual han sido generadas por el propio Novak y presentadas en un texto más reciente (Novak, 1998a).

3 Antes y después del mapa conceptual

Comprender el origen del mapa conceptual permite entender la insistencia de Novak de destacar la relación estrecha entre la teoría del aprendizaje de Ausubel y el mapa conceptual. Es importante, sin embargo, para comprender las prácticas actuales alrededor del mapa conceptual, trazar un *antes y después* de la invención del mapa conceptual. Algunas de las prácticas actuales de investigación y educación conciben al *mapa conceptual* como objeto de estudio, lo que guarda una diferencia respecto al objeto de investigación *que dio* origen al mapa conceptual. Novak inventa el mapa conceptual en el proceso de investigar un objeto distinto al mapa conceptual, se trata del *aprendizaje de conceptos científicos* y que implicaba reconocer el *cambio de los marcos conceptuales* de los sujetos en un momento y circunstancia determinada. El *mapa conceptual* es un objeto cuya existencia de facto, para las nuevas comunidades educativas y de investigación, no surge del análisis de la teoría de Ausubel, sino de las prácticas que este mismo ha dado origen y transformado, es un objeto que ha reestructurado la perspectiva metodológica y didáctica y por ello la forma de concebir el hecho educativo.

Un indicador del cambio en el eje teórico de las prácticas con mapas conceptuales y su investigación puede obtenerse de una revisión de las más recientes publicaciones del tema. De los 164 artículos y *posters* presentados en el Primer Congreso Internacional sobre Mapas Conceptuales en el 2004 (Cañas, Novak, y González, 2004a, 2004b), el 69 % de los artículos (113 de un total de 164) no hacen ninguna referencia bibliográfica a Ausubel, los trabajos que lo citan representan el 31% (51 de los 164). Otra revisión de artículos, publicados en distintos *journals* se encontró que de 26 artículos, 15 no hacen referencia a Ausubel, representado un 58% del total, los artículos sobrantes, el 42% (11 artículos), hacen la referencia a dicho autor (Aguilar Tamayo, 2005). Si bien esta revisión no es exhaustiva puede considerarse representativa de los últimos cinco años.

4 La teoría y la técnica del mapa conceptual

El origen del mapa conceptual, tal como se ha explicado, deja claro que se trata de una unidad compleja de *técnica, metodología y teoría*, comprender el mapa conceptual de Novak implica comprender sus bases técnicas y metodológicas de construcción (Novak, 1998a; Novak y Gowin, 1988) en el contexto de una teoría educativa (Novak, 1982) que las justifica junto con una teoría cognitiva (Ausubel, 2002) que explica los procesos cognitivos implicados. Sin embargo, la expansión del mapa conceptual ha traído consigo la diversidad. *Técnica, metodología y teoría* son re-sintetizadas, integradas o disueltas en espacios teóricos e investigativos distintos. Ello es producto y productor de un centramiento en un nuevo objeto de interés: el *mapa conceptual*.

Publicaciones y congresos en torno al mapa conceptual permiten argumentar que el *mapa conceptual* existe como un objeto cultural significativo para ciertas comunidades educativas y de investigación, estas comunidades

poseen teorías y metodologías de referencia diversas, lo que ha significado distintas formas de apropiación del *mapa conceptual*.

Una estrategia metodológica para analizar este fenómeno, las prácticas que rodean el uso e investigación del mapa conceptual, es a partir del concepto de *sistema representación externa* (Aguilar Tamayo, 2004, 2005), de esta manera se le puede comprender como parte de los *artefactos culturales* disponibles socialmente cuyas funciones son la representación, preservación y construcción del conocimiento (Aguilar Tamayo, 2003; Cole, 2000). Cada *sistema de representación*, posee características estables que los hacen reproducibles e inteligibles por otros seres humanos. El mapa conceptual posee ciertos atributos que, aún en ausencia o inconciencia de las circunstancias y bases técnicas-metodológicas-teóricas que le dieron origen, permiten su elaboración e interpretación a un cierto nivel y de una cierta forma.

Las normas y convenciones que permiten la estabilidad en la creación e interpretación de las representaciones, elaboradas a partir de un sistema de representación externa, constituyen la *técnica*. Analíticamente es posible separar la *técnica* de la *teoría* que sustenta al sistema de representación externo, un ejemplo de ello es la escritura. El sistema alfabético permite la escritura para la representación escrita del pensamiento. La *forma* que adquiere la representación responde a las reglas propias del sistema de representación como de otras convenciones más amplias y complejas, como las científicas (Locke, 1997).

La *técnica* puede estar rodeada de teorías que la explican, la *escritura* como tal puede ser analizada desde la semiótica o la paleografía. Los usuarios de una técnica tienen, en menor o mayor grado, conciencia respecto del trasfondo teórico que sustenta o explica la técnica. Así al escribir un artículo científico, por mencionar un ejemplo, el autor puede conocer explícitamente las leyes gramaticales, normas estilísticas, convenciones de la comunidad científica sobre de la estructura del documento o bien no conocerlas explícitamente y aún así, algunas de ellas, serán aplicadas de manera implícita para producir un *texto* que sea reconocido por una comunidad como *artículo científico*. El conocimiento *sobre la escritura* es distinto al conocimiento que permite *hacer la escritura*, el primero es propio de una perspectiva disciplinaria, el segundo es una *práctica*.

La escritura del mapa conceptual puede compararse con la escritura de textos; es posible elaborar un mapa conceptual sin tener conocimiento explícito de que se representa la *estructura cognitiva* o el *dominio de conocimiento*, pues estos conceptos son originados en un campo disciplinar que permite fundamentar e interpretar la técnica de escritura, es decir, del mapa conceptual. Como resulta evidente, un niño al que se le pida la elaboración de un mapa conceptual no *escribirá* para *representar de manera explícita su estructura cognitiva* pues esto supondría que el niño *conoce y aplica* de manera explícita la teoría de Novak y de Ausubel (Aguilar Tamayo, 2004).

Aunque no existe plena conciencia de las normas o bases teóricas de los sistemas de representación utilizados, su uso contribuye a desarrollos cognitivos en otros campos y algunos de ellos jugaran papeles importantes para el aprendizaje de conocimientos más complejos, así por ejemplo, la *escritura* contribuye a la construcción del *concepto o noción* de *palabra* (Olson, 1999), el *mapa conceptual*, que se ve potenciado por el uso de las *etiquetas o palabras*, permite la construcción de significados de conceptos al momento de ofrece la posibilidad de nombrarlos y representarlos (Novak, 1998a, p.42), posibilitando la construcción de significados y conceptos a través de otros conceptos, lo que facilita la comprensión de conceptos y teorías científicas (Novak y Musonda, 1991).

La *técnica* del mapa conceptual y las propuestas metodológicas para su implementación se sintetizan en la propuesta educativa de Novak (1982) y la teoría cognitiva de Ausubel (2002), pero no determinan las prácticas en torno a ellos. La razón de ello puede encontrarse en el tipo de *producto* que hace posible la *técnica*. Un mapa conceptual es un *texto público* sujeto a la interpretación, como tal cobra independencia de su autor y este no puede controlar por completo la interpretación que hace el lector (Aguilar Tamayo, 2004).

La *producción de textos* a partir de la técnica del mapa conceptual descontextualiza la técnica de sus referentes originales haciendo accesible la representación a lectores que no necesariamente pertenecen a la comunidad que dio origen a la técnica o a la representación en específico (mapa conceptual). Un ejemplo de lo anterior puede observarse en el sitio de Internet del *Center for Mars Exploration* (http://cmex-www.arc.nasa.gov/CMEX/) (Briggs et al., 2004), las instrucciones de lectura en este sitio son breves y no hacen referencia a ningún elemento teórico del mapa conceptual. El mapa conceptual hipermedial que se presenta se constituye como una herramienta para la

representación del conocimiento y es parte de los recursos culturales disponibles socialmente lo que provoca su relativa independencia al contexto teórico y metodológico que le dio origen, al menos para un lector cualquiera.

La *técnica* del mapa conceptual permite la estabilidad del sistema representacional (Aguilar Tamayo, 2004, 2005), establece las normas y orden de elementos gráficos, espaciales y lingüísticos, el producto de estas convenciones es un *texto* reconocido por una comunidad como *mapa conceptual*. La *técnica* no se expresa de manera independiente de los contextos en que se desarrolla la actividad de elaboración del mapa conceptual. Este contexto es variable, su relevancia depende de un marco teórico que signifique dichas prácticas. La elaboración del mapa conceptual tendrá distintas consecuencias y funciones de acuerdo al modelo educativo en el cual se desarrolle la actividad. De cualquier forma es importante observar que el producto de la actividad podrá ser reconocido como un objeto: el *mapa conceptual*; en ese sentido la *técnica del mapa conceptual* es reproducible, estable y cognoscible.

La *técnica de representación* puede ser apropiada en distintos niveles o para distintos propósitos, algunos previstos o explicados por los referentes teóricos que promueve Novak, algunas otras serán innovaciones o usos descontextualizados que son parte de la prácticas, educativas o de investigación, que reproducen el mapa conceptual como objeto de interés. Reconocer que el uso de la técnica del mapa conceptual puede darse en desfase a la teoría y propósitos que le dio origen tiene un significado de mayor importancia que un reclamo de ortodoxia o emancipación del mapa conceptual, significa dar cuenta de la inauguración de un nuevo objeto de indagación y de práctica educativa: *el mapa conceptual*.

5 El mapa conceptual y el replanteamiento de la investigación educativa

Aunque puede resultar obvio el interés de la comunidad educativa y de investigación *acerca del mapa conceptual*, en el contexto de la *metodología de la investigación educativa y psicológica* los efectos no son tan claros. El *mapa conceptual* es un nuevo objeto de interés científico y de la práctica educativa y por tanto un *fenómeno o hecho* cuya existencia trasciende la teoría que lo sustenta. Su uso, a lado de otras formas representacionales simbólicas, lo hace parte del *kit de recursos* que dispone la sociedad para construir, representar y comunicar conocimiento (Pozo, 2003).

Novak (Novak y Musonda, 1991) ofrece con la invención del mapa conceptual un nuevo recurso técnico y metodológico, de esta forma la *técnica* se inserta como parte o elemento de innovación en las *metodologías de investigación*. Este aspecto se ve potenciado con el desarrollo de tecnología informática. El *CmapTools* (Cañas et al., 2004b), herramienta informática para la construcción de mapas conceptuales es, además de un *instrumento de escritura* que facilita la realización del mapa conceptual, una *tecnometodología* que sintetiza la técnica del mapa conceptual tanto como sistema para la representación y también un método de análisis y la construcción de nuevos espacios y hechos educativos, abriendo nuevas posibilidades en la investigación psicoeducativa.

El *artefacto CmapTools*, ha propiciado una nueva complejidad para el *mapa conceptual*. Tal como se ha mencionado, el *mapa conceptual* es actualmente un conjunto de prácticas e intereses de investigación, dentro de ellas se encuentran aquellas previstas u originadas en el cruce teórico de Novak y Ausubel, otras más se descubren y abren nuevas formas de plantear el hecho educativo y la actividad con mapas conceptuales. Las actividades en colaboración o a distancia, las formas de interacción y las nuevas formas de mediación de los sistemas simbólicos compuestos de *mapa conceptual-CmapTools-computadora* son ejemplos de nuevos hechos educativos, la problematización respecto de ellos puede hacerse desde distintas aproximaciones teórico conceptuales, una posibilidad sugerida por Novak es la reinterpretación de las prácticas a partir del concepto de Vygotski (2001) de *zona de desarrollo próximo* (Novak, 1998a, 2002; Novak y Cañas, 2004).

6 El mapa conceptual en la galaxia binaria

Otro aspecto fundamental de la transformación del mapa conceptual es el desarrollo de tecnologías para su escritura. Como otros sistemas de representación externa (escritura, dibujo, pintura, audio) estos deben ser fijados mediante el uso de materiales. Este soporte material posibilita ciertas estructuras y funciones de la representación, así como prácticas sociales respecto a la creación y comunicación de las representaciones (Chartier, 2002). La *escritura* del mapa conceptual requiere de técnica y de tecnologías para su fijación y preservación.

El *CmapTools* (Cañas et al., 2004b) no sólo es un *instrumento para la escritura*, es decir, para el trazado o dibujo, es también un *soporte* para la fijación y conservación que junto con las prácticas de las comunidades académicas conforma un aspecto central de lo que Bolter (2001) llama *sistema de escritura o tecnología de escritura*. El *CmapTools*, considerado como un sistema de escritura, ha contribuido a la adquisición de nuevas funciones del mapa conceptual.

El *CmapTools* es producto y productor del cambio e innovación del mapa conceptual, es por ello que la aplicación no se ha visto confinada a la facilitación del acto concreto de dibujar un mapa conceptual, herramientas como el *sugeridor de conceptos* (Cañas et al., 2004a), o las que permiten la elaboración de mapas conceptuales a distancia y sincrónicamente (Cañas, Ford, Hayes, Brennan, y Reichherzer, 1995) y la hipertextualidad (Briggs et al., 2004) son funciones que *reconocen o inventan* nuevas funciones y aplicaciones pero también modifican el *sistema de escritura*.

Otras funciones del *CmapTools*, como el que hace posible registrar el proceso de construcción del mapa conceptual, facilitan la realización de estudios sobre el cambio de estructuras cognitivas en los estudiantes como el que llevara a cabo Novak y su equipo (Novak y Musonda, 1991). La interconectividad que permite *CmapTools* y que facilita la actividad en colaboración y ha potenciado la construcción de comunidades, (véase por ejemplo el proyecto *WWMaps*: http://www.2wmaps.com/), abriendo o ingresando un tema de actualidad: la *educación intercultural*

7 Hacia una teoría del mapa conceptual

La teoría del mapa conceptual deberá plantear como objeto de estudio precisamente al *mapa conceptual*, lo que implica un reacomodo o desplazamiento de distintas teorías que actualmente confluyen en el escenario de prácticas educativas y de investigación alrededor de este objeto.

El mapa conceptual, en su dimensión técnica, existe de manera estable, las normas gráficas y espaciales así como las lingüísticas dan lugar a un sistema representacional que permite la representación del conocimiento y facilitan y/o exigen del desarrollo de ciertas competencias y formas de conocer el mundo. Dada la aceptación y adaptación de la técnica a nivel mundial puede considerarse como parte de los *artefactos culturales* (Cole, 2000) y *sistemas simbólicos* (Pozo, 2003) disponibles socialmente para la construcción, comunicación y preservación del conocimiento.

La teoría sociocultural ofrece una perspectiva para indagar y explicar al mapa conceptual en el contexto de un nuevo orden de práctica educativas y de la problematización (Aguilar Tamayo, 2005). El concepto de *zona de desarrollo próximo* (Vygotski, 2001, p.239), tal como advierte Novak (2004, p.464), ofrece otra forma complementaria y/o alternativa de explicar el *modelo educativo* formulado y propuesto Novak (Novak y Musonda, 1991) y que fue contexto para el origen del mapa conceptual. A partir del concepto de zona de desarrollo próximo surgen otros que ayudan a comprender las funciones sociales y culturales así como cognitivas del mapa conceptual, por ejemplo el concepto de *mediador semiótico* (Wertsch, 1998) que permitiría explicar la función del mapa conceptual en los procesos de interpretación de los textos (Aguilar Tamayo, 2002), o el concepto de *artefacto cultural* (Cole, 2000) que permite una aproximación más compleja para describir las funciones de *CmapTools*, entre muchos otros conceptos que tendrán que ser planteados por la comunidad educativa y de investigación.

La teoría del mapa conceptual se vislumbra como un espacio de reflexión y problematización interdisciplinario. Novak recuerda acerca de las teorías que:

> "Las teorías se basan en los conceptos y en las prácticas existentes, en un momento dado, por ello es inevitable que las teorías cambien (…). Las teorías sirven para unir conceptos o para sugerir formas de relación entre conceptos, por lo que constituyen a modo de conceptos de orden superior, en tanto pueden sugerir orden o relación entre conceptos menos inclusivos" (Novak, 1982, p.18)

Este trabajo ha permitido advertir un cambio de prácticas y de sus propósitos, es una provocación para sugerir algunos conceptos y las relaciones entre ellos, se han presentado algunos apuntes para contribuir a la construcción de una teoría sobre el *mapa conceptual*.

8 Referencias

Aguilar Tamayo, M. F. (2002). Mediador hipertexto, una propuesta para facilitar la comprensión de textos. En: INFODEX (Ed.), *Educación. Retos de la alfabetización tecnológica en un mundo en Red* (Vol. I, pp. 15-23). España: Junta de Extremadura, Unión Europea, Infodex.

Aguilar Tamayo, M. F. (2003). A model of Educational Hypertext taken from Vygotsky's Theorical Perspective. En: A. Méndez-Vilas & J. A. Mesa Gonzáles (Eds.), *Advances in Technology-based Education: Towards a Knowledge-base Society*. España: FORMATEX.

Aguilar Tamayo, M. F. (2004). *El Mapa Conceptual: Un texto a interpretar*. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Aguilar Tamayo, M. F. (2005). *Representaciones visuales-conceptuales del conocimiento y estructura del hipermedia educativo.* Tesis no Publicada, Universidad Autónoma del Estado de Morelos, Cuernavaca, México.

Ausubel, D. P. (2002). *Adquisición y retención del conocimiento. Una perspectiva cognitiva*. España: Paidós.

Bolter, J. D. (2001). *Writing Space. Computers, Hypertext and the Remedation of Print*. USA: Lawrence Erlbaum Associates, Publishers.

Briggs, G., Shamma, D. A., Cañas, A. J., Carff, R., Scargle, J., & Novak, J. D. (2004). *Concept maps applied to Mars exploration public outreach.* En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cañas, A. J., Carvalho, M., Arguedas, M., Leake, D. B., Maguitman, A., & Reichherzer, T. (2004a). *Mining the web to suggest concepts during concept map construction.* En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004b). CmapTools: A Knowledge Modeling and Sharing Environment. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Cañas, A. J., Ford, K. M., Hayes, P. J., Brennan, J., & Reichherzer, T. (1995). *Knowledge Construction and Sharing in Quorum.* Artículo presentado en World AI in Education Conference 1995, Washington, DC.

Cañas, A. J., Novak, J. D., & González, F. M. (2004a). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. 1). España: Universidad Pública de Navarra.

Cañas, A. J., Novak, J. D., & González, F. M. (2004b). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. 2). España: Universidad Pública de Navarra.

Coffey, J. W., Carnot, M. J., Feltovich, P. J., Feltovich, J., Hoffman, R. R., Cañas, A. J., & Novak, J. D. (2003). *A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support* (Technical Report submitted to the US Navy Chief of Naval Education and Training). Pensacola, FL: Institute for Human and Machine Cognition.

Cole, M. (2000). *Cultural Psychology. A once and future discipline*. Cambridge: Harvard University Press.

Chartier, R. (2002). *El mundo como representación. Historia cultural: entre práctica y representación*. España: Gedisa.

Kommers, P., & Lanzing, J. (1998). Mapas conceptuales para el diseño de sistemas hipermedia. Navegación por la Web y autoevaluación. En: C. Vizcarro & J. A. León (Eds.), *Nuevas tecnologías para el aprendizaje* (pp. 103-127). España: Pirámide.

Locke, D. (1997). *La ciencia como escritura*. España: Cátedra.

Novak, J. D. (1982). *Teoría y práctica de la educación*. España: Alianza.

Novak, J. D. (1998a). *Conocimiento y aprendizaje. Los mapas conceptuales como herramientas facilitadoras para escuelas y empresas*. Madrid: Alianza.

Novak, J. D. (1998b). The Pursuit of a Dream: Education Can Be Improved. En: J. J. Mintzes, J. H. Wandersee & J. D. Novak (Eds.), *Teaching Science for Understanding. A Human Constructivist View* (pp. 3-28). USA: Academic Press.

Novak, J. D. (2002). Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappopriate Propositional Hierarchies Leading to Empowerment of Learners. *Science Education, 4*(86), 548-571.

Novak, J. D. (2004). *A Science Education Research Program that led to the Development of the Concept Mapping Tool and New Model for Education.* En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Novak, J. D., & Cañas, A. J. (2004). *Building on New Constructivist Ideas and CmapTools to Create a New Model for Education.* En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Novak, J. D., & Gowin, B. (1988). *Aprendiendo a aprender*. Barcelona: Martínez Roca.

Novak, J. D., & Gowin, B. D. (1984). *Learning How to Learn*. USA: Cambridge University Press.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28*(1), 117-153.

Olson, D. R. (1999). *El mundo sobre el papel. El impacto de la escritura y la lectura en la estructura del conocimiento*. España: Gedisa.

Pozo, J. I. (2003). *Adquisición de conocimiento*. España: Morata.

Shavelson, R. J., Lang, H., & Lewin, B. (1994). *On concept maps as potential "authentic" assesments in science* (CSE Technical Report No. 338). Los Angeles, CA: National Center for Research on Evaluation, Standards and Student Testing (CRESST), UCLA.

Vygotski, L. S. (2001). *Obras Escogidas II. (Incluye Pensamiento y lenguaje. Conferencias sobre psicología)* (2a. ed.). España: Visor.

Wertsch, J. V. (1998). *Mind as Action*. USA: Oxford University Press.

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PRECONCEPTIONS REGARDING CONCEPT MAPS HELD BY PANAMANIAN TEACHERS

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Abstract. Many studies have shown that, as a tool for the organization and representation of knowledge, concept maps can support meaningful learning and knowledge construction processes. Good concept maps can lead to the discovery of new and unsuspected relations among concepts, thereby stimulating students' creativity. In Panama, concept maps have been known and used for years. This study examines Panamanian public elementary schoolteachers' preconceptions about concept maps and their use. The study was carried out with teachers beginning training in the *Conéctate al Conocimiento* Project's workshops, and shows that although a very high percentage of teachers are familiar with concept maps, and a great many claim to use them in their classrooms, most of them have serious conceptual errors regarding this tool. Results highlight possible reasons why concept maps have not had the expected impact in Panama's schools, and allow us to make adjustments to the teaching strategies implemented at the workshops in order to improve their outcome.

1 Introduction

In what has come to be known ad the *Information and Knowledge Society*, it is generally agreed that individuals will need to be able to adapt to rapid, continual and turbulent change, both in their personal lives and in the workplace. In such a setting, the ability to construct new knowledge, be creative, and work collaboratively, will prove invaluable. In schools, children have the opportunity to acquire and practice these skills through work with various pedagogical tools such as concept maps.

Numerous studies (see Coffey et al., 2003) have demonstrated the potential of concept maps in helping students construct their own knowledge, as well as in stimulating their creativity. Additionally, with the advent of concept-mapping computer programs and their integration with Internet, many novel forms of collaborative work have become possible.

1.1 Concept maps

Concept maps are not new in education. They were developed during the 70's by Joseph Novak and his colleagues at Cornell University, as a tool to help record and understand changes in students' comprehension of science concepts. Over the years, their potential to involve students in significant learning processes became evident. This was eloquently presented in the book *Learning how to learn* (Novak & Gowin, 1984), thus contributing to spread the use of concept maps throughout the world.

A concept map is made up of *concepts* joined by *linking words* or *phrases* to form *propositions.* Novak (1998) defines a concept as "a perceived regularity in objects or events, or in representations of objects or events, which is designated by a label." More informally, a concept can be thought of as the mental image we associate to a word or set of words. As the term itself suggests, propositions "propose" or state something; thus they constitute semantic units or units of meaning. The linking phrase expresses the relationship that is claimed to exist, in a given context, between the joined concepts. There is no specific limit as to the number of words a linking phrase may contain. However, as a general rule, relations should be expressed as clearly and succinctly as possible.

Concept maps can support meaningful learning in many ways. In what follows we highlight only some of these ways. According to the Theory of Meaningful Learning (Ausubel, Novak & Hanesian, 1978), in order for meaningful learning to take place, the learner must possess a framework of relevant, well-organized knowledge into which new knowledge can be inserted in a flexible and dynamic manner. The problem, in practice, is how to reveal this knowledge structure. As a tool for the organization and representation of knowledge, concept maps help expose the knowledge that a learner has on a given topic or subject. Due to their simple proposition-based structure, it is easier to detect conceptual errors in a concept map than in a piece of linear text, where the language itself often obscures clear ideas, or disguises erroneous ones. In this manner, concept maps provide a structure into which a students can insert new concepts and propositions, whilst they re-examine previous ones.

1.2 The Conéctate al Conocimiento Project

Conéctate al Conocimiento (Tarté, 2006) is a project to transform Panamanian education. It is under the responsibility of the President's Secretary for Government Innovation and, presently, is directed at 4th, 5th and 6th grade teachers of Panama's public elementary schools. The project involves two mutually complementary aspects: 1) 2-week training workshops in the use of specific pedagogical and technological tools, and in the application of instructional methods and strategies conducive to meaningful learning in students; and 2) follow-up visits to schools to offer necessary pedagogical, technical and emotional support to guarantee the correct implementation of the workshops' content. During its first year (2005), the project incorporated over 130 schools, as part of its plan to include 1000 schools in five years. Almost all 4th , 5th, and 6th grade teachers from the participating schools were trained.

Concept maps are the main pedagogical tool on which the project is based. Throughout the workshops, concept maps are constructed, for the most part, by means of the computer program CmapTools (Cañas et al., 2004).

The task ahead is enormous and the challenges many, not least of which are the preconceptions teachers already have about concept maps and their use. In Panama, concept maps have been known for almost 20 years. Most elementary and secondary level teachers who have studied pedagogy at Panamanian universities have been exposed to concept maps. Unfortunately, it appears that most of them have a considerable number of conceptual errors. The purpose of this study, therefore, is to find out just what Panamanian teachers know about concept maps and their use. In this regard, the Conéctate Project offers a unique opportunity to collect valuable information from teachers just beginning their training. Knowing beforehand what teachers know about concept maps can help devise more effective training strategies which, it is our hope, will better guarantee a significant positive impact of the use of concept maps in Panama's elementary education.

2 **Materials and methods**

The data on which this article is based was obtained through a questionnaire given to 6 different groups, of approximately 20 teachers each, over the course of workshops 5-10, beginning in July 2005 and ending in September 2005. The full sample consists of 115 teachers.

The project directors are responsible for selecting the schools that participate in the program and, as a matter of policy, choose schools from all over the country. They too are in charge of assigning teachers to the various classrooms[1]. Generally, all schools participating in a given workshop are represented in each of the classrooms. As a result, our sample includes schools from 8 of Panama's 9 provinces[2], and from Kuna Yala, one of Panama's 5 Indian reservations. Furthermore, the places of birth of those included in the sample cover most of the country. Thus, although the sample is neither random nor representative in a strict statistical sense, it is sufficiently diverse so as to provide a fairly good idea of what goes on nationwide.

The instructions supplied to the teachers along with the questionnaire included a brief explanation of the purpose of the study, namely, to improve the effectiveness of the workshops. The document stated that all information was strictly confidential, and that under no circumstances would it be possible to identify any individual in the study's written report. Aside from the basic demographic information, all questions were multiple-choice. Only one choice per question was allowed. Emphasis was made that answers should reflect personal experience as accurately as possible. The teachers were supervised at all times throughout the giving of the questionnaire and, inasmuch as was possible, were kept from talking to each other. The questionnaire took about 15 minutes to complete, and was always given on the first day of workshop, as soon as the teachers were settled into their assigned classroom.

It must be pointed out that the questionnaire given in each of the 6 workshops covered by the study are not entirely identical. Changes were made as the need to modify certain questions or include new ones became clear. Consequently, the sample size may be somewhat different for different questions. The value of *n* next to each statistical result indicates the size of the sub-sample; if none appears, the statistic is based on the full sample.

[1] During workshops 5 and 6 the project had 4 classrooms; from workshop 7 on, the number of classrooms increased to 8.
[2] At the time this study was conducted, no schools from Panama's Darién province had participated.

3 Results

The average age of the 115 teachers in the sample is 40.2 years, the range being 20 to 56 years. Approximately 70% of those surveyed completed their high school education at a Normal school, and 40% of them attended one particular Normal school, the Escuela Normal Juan Demóstenes Arosemena, in the province of Veraguas. As for higher education, 87% attended university. Specifically, 9% completed 1 to 2 years of university studies, 34% completed 3 to 5 years, 42% completed more than 5 years; 15% said they had either not attended university or had not finished their first year. Regarding years of service, 15% of those surveyed had 1-5 years of work experience, 23% had 6-10 years, 17% had 11-15 years, 15% had 16-20 years, and 30% had over 20 years of work experience $(n = 94)$.

The sample includes teachers with different levels of familiarity and comfort with technology. For instance, 46% $(n = 76)$ of the teachers worry they might damage a computer by touching it, 46% $(n = 74)$ fear that others know more about computers than they do, and 26% $(n = 76)$ worry about appearing foolish while using a computer. In terms of frequency of use, 47% report never having used a computer, 36% have used one once in a while, 10% use one often, and 8% use one all the time $(n = 92)$, Finally, only 20% of teachers indicate they possess an e-mail account $(n = 35)$.

Getting into the matter of concept maps, our results show that practically all of those surveyed are familiar with concept maps, and a large percentage of them claim to use them in their classes (figure 1).

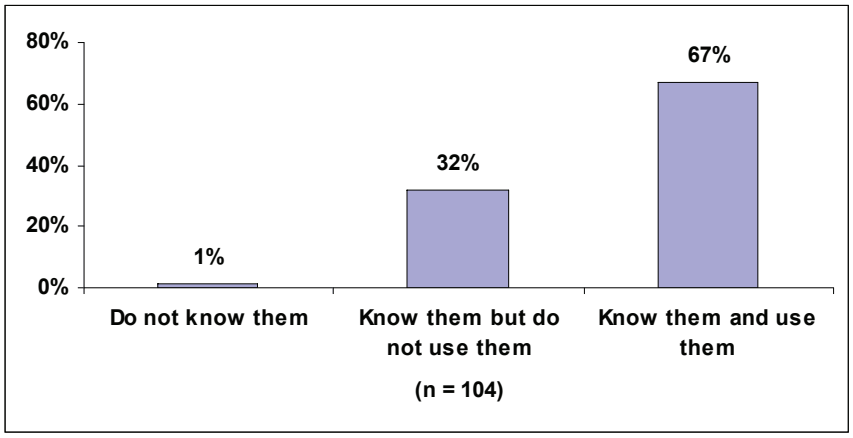


Figure 1. Familiarity with concept maps.

Figure 2 shows the various sources through with teachers have first come into contact with concept maps. As can be seen, universities, particularly *university professors*, have been the main conduit through which teachers have come to know this tool. Seminars are the second most common source. It's worth pointing out that although the questionnaire did not ask teachers to specify who was in charge of the particular seminar they attended, it is likely that it was either a university or the Ministry of Education, since in Panama it is generally the case that these institutions are the ones who organize such events. *Colleagues* and *books* come in third and fourth, respectively. Regarding the latter option we must note that it was first added to the questionnaire in workshop 7, but it wasn't until workshop 9 that we realized teachers were not distinguishing between regular books (which is what we had in mind) and their students' *text books*. Although later versions of the questionnaire added this distinction, for this article we were unable to obtain sufficient data to present reliable statistics. Finally, only 5% report learning about concept maps through a high school teacher. This seems somewhat surprising given that most educators in our sample attended Normal schools.

As to the benefits of concept maps for students, we found that practically all teachers in the sample (93%) agree that the most important benefit for students is that they "help them organize and represent their ideas." Few believe

their usefulness lies in that they "summarize material so that students can learn it faster" (5%), or "motivate students because they don't have to write so much" (3%).

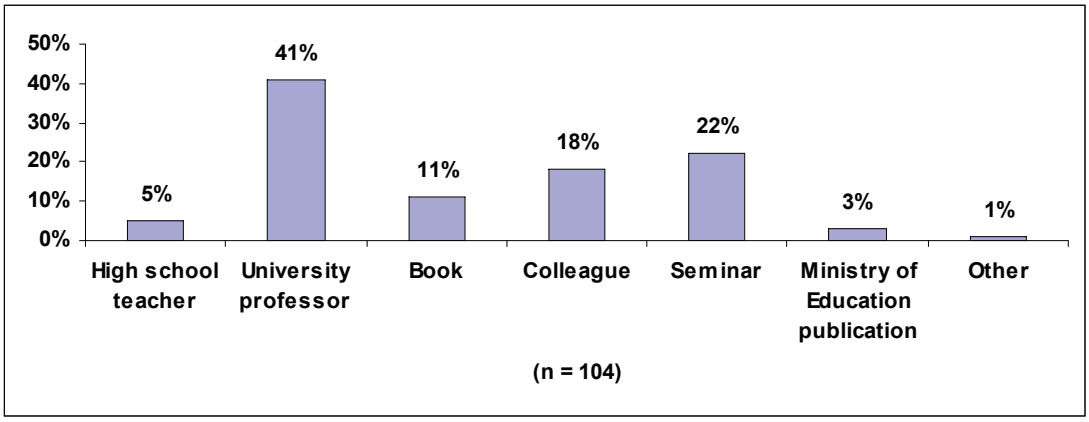


Figure 2. Primary source of information on concept maps

These results stand in contrast to the results on the didactic use that teachers make of concept maps (figure 3). The most common practice is for teachers to construct a concept map in class for students to memorize (51%), followed by providing students with an already-made concept map for them to memorize (32%). Fewer than 5% of educators allow students to construct their own concept map.

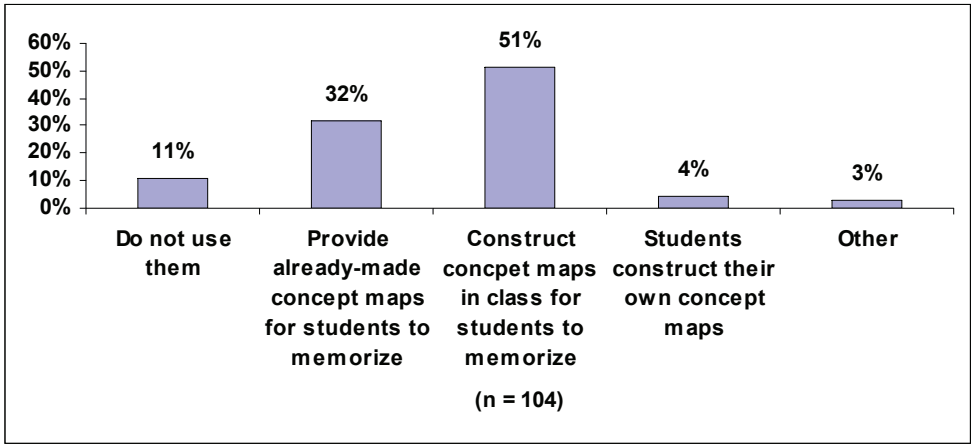


Figure 3. Main didactic use concept maps

As a tool for evaluation, 39% of teachers have never used them; 58% have done so by providing fill-in-the-blank structures, where students fill in either concepts, linking phrases, or both. A mere 1% of teachers who use concept maps as an evaluation tool actually ask students to construct a complete map from scratch (figure 4).

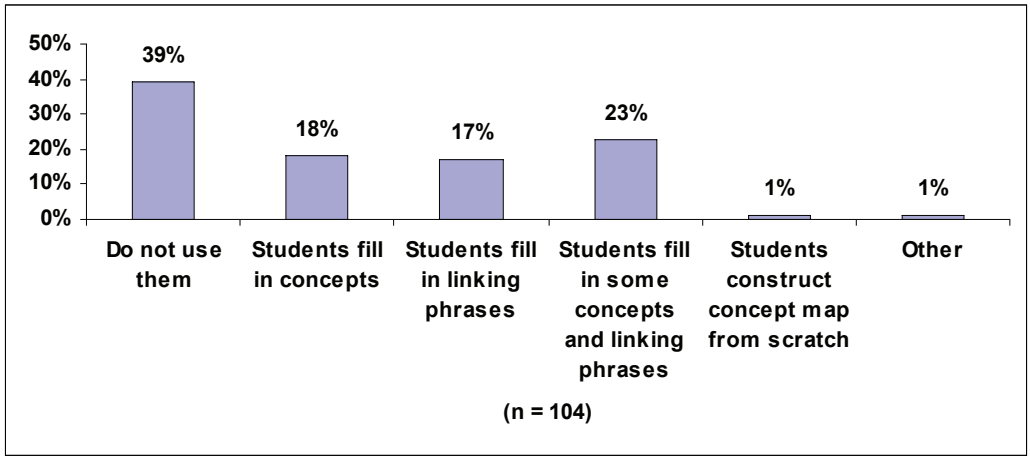


Figure 4. Main use of concept maps as an evaluation tool

Figure 5 shows the preconceptions teachers hold regarding linking phrases. Though the vast majority (97%) concur that linking words are necessary, 38% believe that only *prepositions* can be used, whereas 28% believe that *only one* word can be used, albeit any kind of word. Only a third (32%) of teachers believe that linking phrases can contain one or more words, of any kind.

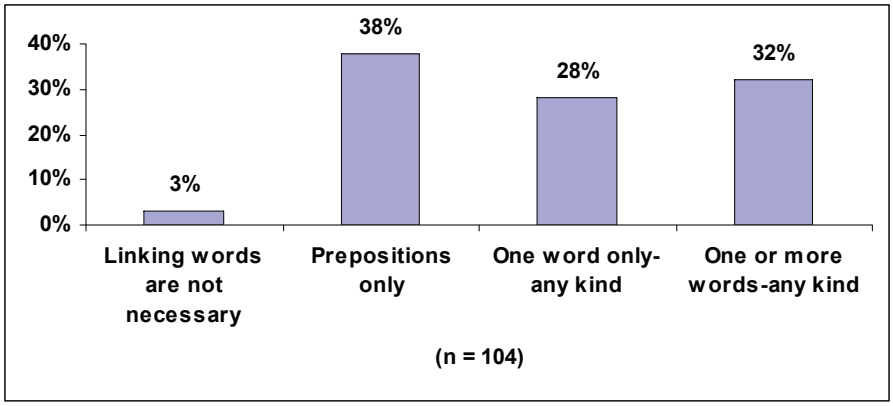


Figure 5. Preconceptions on the number and type of linking words

An interesting result is that 51% $(n = 47)$ are of the idea that connecting lines between concepts must not cross each other, and exactly half consider that connecting lines must be straight lines $(n = 36)$; 27% believe lines can not cross *and* can not be curved $(n = 30)$.

The survey inquired about other aspects of concept maps, such as the shape of the boxes in which concepts are written, the use of upper and lower case letters in writing concepts and linking phrases, the use of arrows on connecting lines, and the direction in which concept maps are read. We found that 83% feel boxes can be of any shape, but 16% say they must be elliptical. More than half (53%) believe concepts must be written in upper case, linking words in lower case; 11% say concepts must be in upper case, linking words any way; and 36% say it doesn't matter how concepts or linking words are written. The arrow at the tip of connecting lines is obligatory for 32% of surveyed teachers, optional for 15%, and optional except in case it is unclear how to read the concept map for 48% of teachers. Lastly, 30% of sampled educators say concept maps are always read in the downward direction, 22% say they ought to be able to be read in both directions, and 42% believe they are read downward unless arrows indicate otherwise.

4 Discussion

We open this discussion section with the following question: In view of the high percentage of teachers (67%) who, as indicated by this study, use concept maps, and the potentiality of concept maps to facilitate meaningful learning, why is it that this is not reflected in the quality of Panamanian education? Perhaps the teachers themselves provide the answer.

Our results show that there are serious inconsistencies between what Panamanian educators think about concept maps and what they do with them. On the one hand, we find that when asked about the major benefit of concept mapping for students, 93% assert that they help them organize and represent their ideas. Nonetheless, when it comes to using them in the classroom as a tool for learning, fewer than 5% permit students to construct their own concept maps on a given topic. The vast majority of teachers (over 95%) expect students to memorize the concept maps they have given them, or the ones they have constructed in class. The general notion seems to be that, on any given topic, there is one "correct" concept map, and students must learn it. Needless to say, this entirely contradicts the theory on which concept maps are based. This equivocal notion is further reinforced by the fact that concept maps are generally used to study eminently classificatory curricular content[3] (types of plants, types of animals, types of words, among others), which does not easily lend itself to the construction of "personal" concept maps, i.e., concept maps that allow some degree of variation among one another. This is worrisome because as Moreira points out, "inasmuch as students use this technique to analyze articles, texts, chapters from books, novels, laboratory experiments and other educational materials pertaining to the curriculum, [in this measure] will they be using concept mapping as a resource for [meaningful] learning"[4] (Moreira, 2005). Hence, the picture that emerges reveals concept maps essentially being used to encourage memorization rather than construction of meaning.

Something similar takes place when using concept maps as an evaluation tool. Of the 61% of educators who use concept maps to evaluate their students, only 1% ask them to build a concept map from scratch. The usual practice is to provide students with a concept map framework for them to fill in the missing concepts and/or linking phrases. Once again, this is a practice that fosters memorization, not meaningful learning.

Cross links are an extremely important element of concept maps (Novak, 1998). Cross links are propositions that connect concepts located in different regions or domains of a concept map. Their importance resides in the fact that relations established through cross links tend not to be obvious and thus, require additional effort in terms of thought and creativity. Evidently, in order to establish a cross link, connecting lines may have to go across from one side of the concept map to the other, which often means crossing other connecting lines. However, as our results show, half of the teachers (51%) believe lines in a concept map can not intersect each other. This suggests that in their minds, cross links are not allowed as a possibility. Occasionally intersections can be avoided by using curved lines. But as our results show, 27% of teachers who do not admit intersections also do not admit curved lines, thereby eliminating altogether the possibility of connecting ideas in different regions of a concept map, even when connecting lines do not cross each other. These results provide evidence of a linear way of thinking which, once more, makes plain the gross inconsistencies between theory and practice held by many educators with regard to concept maps. For, if concept maps are a tool that promotes meaningful learning, and if learning in a meaningful way requires relating ideas, how can we hope to achieve this type of learning when the we deny the very physical actions needed to establish relationships between ideas?

Of much less consequence, from the point of view of their impact on education, would be teachers' preconceived ideas about the purely aesthetical elements of concept maps, if it were not for the importance that they themselves give to them. Throughout the 6 workshops during which the data for this article was collected, teachers sometimes strongly questioned the trainers about such aspects as shape of boxes, use of upper and lower case letters, among other things. Although many were receptive to the notion that such things were entirely subjective, others insisted in the need to establish "uniform criteria." Sadly, the reasons they gave to justify their thinking generally revealed that, at some point in their experience with concept maps they had come across a professor (usually a university professor) who had penalized their work for not complying with certain pre-established aesthetic criteria.

As a result of both the interest awakened by our questionnaire and the workshops themselves, a number of teachers provided us with originals and photocopies of texts they had used whilst studying concept maps at the university. In all of them we discovered limitations, inconsistencies and conceptual errors similar to the ones

[3] This statement is derived from our experience with teachers in the workshops, and was not part of the survey.
[4] Translation by Norma Miller.

maintained by the surveyed teachers. We were surprised, moreover, that from one workshop to the next we always got the same two or three texts. Thus, it would seem that such texts have contributed to a limited and distorted understanding of concept maps in both university professors and elementary school teachers, which simply perpetuates rote learning by Panamanian students.

5 Conclusions

This study set out to explore the preconceptions regarding concept maps and their use held by Panamanian teachers who were beginning training at the Conéctate al Conocimiento Project. Results indicate serious conceptual errors that not only limit but might actually annul any cognitive benefit resulting form this pedagogical tool. Results also show that teachers' primary source of information on concept maps are university professors. Thus, it would seem urgent to revise what is taught about concept maps at the university level. Additionally, it seems imperative to improve the quality and availability of materials in Spanish, as part of the problem might lie in the use, year after year, of the same conceptually limited or incorrect texts.

Specifically, in the context of the Conéctate al Conocimiento Project, knowing teachers' preconceptions about concept maps beforehand is important because it can help tailor the content and pacing of the workshops, and allow trainers to better prepare to handle a variety of pedagogical situations that might arise in the course of instruction. Some strategies that we believe may be useful to help overcome these preconceptions are: 1) presentation throughout the workshop of concept maps made by both children (including Panamanian students) and experts illustrating propositional structure, cross-links, and a number of different aesthetics; 2) use of devises such as "conceptual dice" (Hughes et al., 2006) as a means to break away from standard text-book statements and help generate novel propositions; 3) group discussions of maps to provide feedback and stimulate search for unnoticed connections among concepts; 4) introduction to Internet early in the workshop (usually third day) as a source of information and resources to enrich maps; and 5) application of concept maps in a variety of situations to illustrate their many possible uses.

To end, we return to the question with which we began the discussion section: Given the extended use of concept maps in Panama, why is it that they have not had the expected impact in Panamanian education? It might well be that a major part of the answer lies in the erroneous notions that Panamanian teachers have regarding concept maps and their use which this study has made evident.

6 Acknowledgements

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7 Bibliografía

Ausubel, D. P., Novak, J. D. & Hanesian, H. (1978). *Educational Psychology: A Cognitive View*. 2nd ed., New York: Holt, Rinehart and Winston.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M. & Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak, & F. M. González (Eds.) *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, vol. I, Pamplona, Spain: Universidad Pública de Navarra, 125-133.

Coffey, J. W., Carnot, M. J., Feltovich, P. J. Feltovich, J., Hoffman, R. R., Cañas, A. J., & Novak, J. D. (2003). A Summary of Literature Pertaining to the Use of Concept Mapping Techniques and Technologies for Education and Performance Support. IHMC, Pensacola, FL, Technical Report submitted to the US Navy Chief of Naval Education and Training.

Hughes, G., J. Barrios, D. Bernal, A. Chang, A. J. Cañas (2006). Los Dados Conceptuales: Un Juego para Aprender a Construir Proposiciones. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Moreira, M. A. (2005). Mapas Conceptuales y Aprendizaje Significativo. Available at: http://www.if.ufrgs.br/~moreira/mapasesp.pdf, [Consulted: September 18, 2005].

Novak, J. D. & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

Novak, J. D. (1998). *Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations*. Mahwah, NJ: Lawrence Erlbaum Associates.

Tarte, G. (2006). Conéctate al Conocimiento: Una Estrategia Nacional de Panamá basada en Mapas Conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

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RANKING CONCEPT MAP RETRIEVAL IN THE CMAPTOOLS NETWORK

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Abstract. Concept maps are very good at organizing knowledge about a wide variety of subjects. However, they present some difficulties and opportunities when it comes to the retrieval of concept maps based on individual query terms. In this paper, we review the search architecture of CmapTools and some of the key issues involved in the ranking of concept maps search results. We compare several different methods for ranking the results of a query term search on concept maps. We draw conclusions and present some ideas for future work.

1 Introduction

The use of concept maps has expanded rapidly since their introduction in the 1970's by Dr. Joseph Novak (Novak and Gowin 1984). Concept maps are two-dimensional, visual representations of the relationships between concepts representing individual knowledge, collaborative group consensus, and corporate memories (Cañas, Hill et al. 2004; Coffey, Eskridge et al. 2004). Users from elementary school to universities have used concept maps to develop new ideas, organize information, and preserve knowledge in a wide variety of subject domains (Novak 1998).

CmapTools is a client server software environment developed at the Florida Institute for Human & Machine Cognition (IHMC) that facilitates the construction and sharing of concept maps. The software has been downloaded numerous times in countries around the world, and over 100 public CmapServers have been established that enable users to share their own concept maps, collaborate with others, and discover information on a wide range of subjects.

The task of discovering relevant information in concept maps is the focus of this paper. CmapTools has a search facility that integrates the results of search queries that are executed simultaneously on client's local search indices as well as on the indices of all other public servers. The number of results returned from even a simple search can be on the order of several hundred concept maps and other resources. In order to enhance the user experience with CmapTools, the first results returned should be the most relevant resources for the query issued.

The growing CmapTools network has prompted us to investigate the current search result ranking method, to quantify its performance, and to compare it to other methods that have the potential to produce more relevant rankings. This paper presents preliminary results on an experiment designed to compare and quantify CmapTools search ranking method performance. The paper is structured as follows: First, we describe the current client-server search architecture of the CmapTools environment. We then discuss the general characteristics of search in CmapTools. The competing ranking methods and experiment design are described, and the results of the experiment are presented. We discuss the findings from the experiment, and discuss some ways to improve the experiment and results.

1.1 Search Architecture

The search architecture in CmapTools encompasses searching over three different groups of indices and integrating the results at the client in the standard CmapTools search window (see Figure 0). A client side search index is created for the concept maps and resources stored locally on the user's "My Cmaps". This index will contain all of the information about the resource stored locally, and will be accessible only by the local user. Each server creates and maintains a search index that is typically forwarded to an IndexServer (the solid lines in Figure 0). The IndexServer is a special CmapServer whose purpose is to aggregate CmapServer search indices and execute search requests over the entire population of indices at one time. Each time a search is performed, queries are issued to the local index, all available IndexServers, and directly to any CmapServer that is not registered with an IndexServer. These results are grouped and

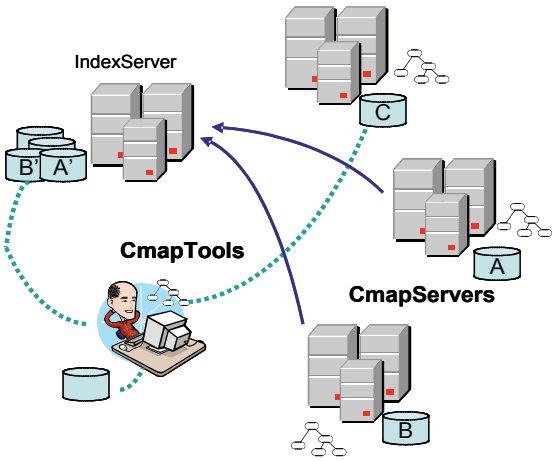


Figure 0. CmapTools Search Architecture

sorted for presentation in the Search dialog box. When a search result is found, it is returned to the client interface (see Figure 1). The user can double-click on the search result to open the resource directly from the server on which it is stored.

1.2 General Search Characteristics

The search index is created at startup time and is updated whenever concept maps or resources are modified or saved. The search index contains information from the concept map, such as the concept and linking-phrase labels, as well as meta-data, such as the description, keyword, title, and author of the map. By default, all indexed information is used to satisfy search queries: A query term that appears in the description or keyword fields of a concept map will cause the map to be retrieved.

The standard search in CmapTools makes a number of default assumptions:

1. **All queries are OR'ed**. Executing a search for the query *Tangerine Apple*, will result in documents that match the word *Tangerine* or documents that match the word *Apple,* and possibly, but not necessarily both. To get documents that are required to match both words, the query terms must be explicitly AND'd together, like this: *Tangerine AND Apple*.
2. **All queries are case insensitive**. All indexed content of the concept map is converted into lowercase text during index creation. As the query is issued, it is also converted to lowercase text.
3. **Search terms with greater than four characters are searched using "wildcards"**. If you search for the term *Apple*, the CmapTools search facility internally searches for **apple**, which means that it will return documents containing the words *Snapple*, and *applesauce*. Wildcards are not used on search terms with less than four characters because doing so can result in the generation of very large (internal) queries that significantly detract from the performance of the search engine.
4. **Search terms enclosed in quotes are treated as a single term**. Searching for "*Tangerine Apple",* will return all documents where the words *tangerine* and *apple* are next to each other and separated by a space. This makes it easy to search for documents containing things like the names of people. If you were to search for *Mark Johnson* you would get all documents containing the words *mark* or *johnson*. However, if you searched for *"Mark Johnson"*, only documents with that particular name will be returned. Also, wildcards are not added to search terms enclosed in quotes.
5. **Boolean ordering can be accomplished using parentheses**. To order the logical combinations in a query, parentheses can be used. For example, the query *animal plant* returns resources that are either plants or animals. But to prevent search from returning manufacturing plants as well as green plants, we can write the query like this: *animal (plant AND green)*. Now the search returns documents that are either

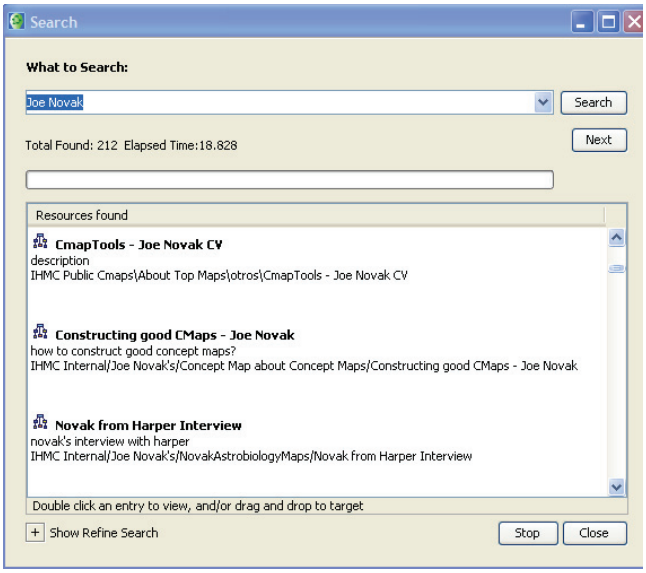


Figure 1. Results are integrated in the Search dialog.

an *animal* or that contains both *plant* and *green*. Note that the documents containing *plant* and *green* may also contain the word *animal.*

6. **Handling Negation.** Negation is handled using the *NOT* query keyword. One important limitation CmapTools handling of negation is that it is not proper to search using only negation. Thus, a query such as *NOT manufacturing* logically means the search should return all resources do not contain the term *manufacturing*, but is illegal in CmapTools. So an additional term must be added to this. Thus, a search for *plant NOT manufacturing* returns documents that mention the term *plant* but that do not mention the term *manufacturing.*
7. **Handling permissions.** The results of a search are filtered by the permission settings on the individual servers. Because of this, users who do not have authorization to open a resource, for example, by clicking on it in the Views window, will not receive that resource as a search result. This has implications for users who protect their maps on a server, but try to access them from another CmapTools client. Unless they have entered a username and password that can open the resources stored in the protected folder, the resources will not be returned as part of the search.

For the purposes of this experiment, only assumptions 1, 2 and 3 are utilized.

2 Ranking Methods

The inverted-tree indexing structure used by CmapTools ensures that a document will be retrieved if it matches any query term. There is no limit on the number of results retrieved from the index present on the CmapTools client. However, we currently limit the number of results retrieved from CmapServers and from the IndexServers. Because of this, it is important that the most relevant maps are conveyed to the user first. The ranking methods order the list of search results with the goal of providing the most relevant search results at the top of the list. We are interested in improving the search result ranking in CmapTools because finding relevant results quickly not only improves productivity, but also enhances the user experience.

2.1 Keyword Match (KM)

This is the most simplistic matching algorithm used in this test, and is also the default ranking algorithm for CmapTools. It simply counts the number of query term matches in the document, and normalizes this result to the number of terms in the query, with bonuses for keyword matches in the title (0.001), and for matching concept maps (0.0001).

$$Score_{km} = \sum_{i=0}^{K} t_i \Big/ K + TITLEBONUS + CMAPBONUS$$

Despite its simplicity, this approach has demonstrated generally satisfactory results. This is in part due to the most common type of query being issued is a "location" query. That is, the user remembers a seeing particular map, but not where the map was. Because it is remembered, it is usually a simple task to search with query terms that will easily discriminate the desired map. By issuing the query with multiple discriminatory terms, and ranking the results according to how many of the terms are matched in the indexed documents, the desired map (or resource) will often appear in the top results.

However, as the adoption of CmapTools grows, we envision more use of the search as a knowledge exploration tool. That is, users will search concept maps to gain new knowledge rather that to locate maps that they know already exist.

2.2 TF-IDF (TI)

The TF-IDF methodology was developed by (Salton and McGill 1989). The TF-IDF vector space model of information retrieval is described in (Baeza-Yates and Ribeiro-Neto 1999) as a clustering model where the intra-cluster similarity term (to be maximized) is defined by the frequency of the term in the document (which indicates how well the term describes the document), and the inter-cluster similarity (to be minimized, or dissimilarity to be maximized) is the inverse document frequency. This factor is based on the

idea that the more a term is shared between documents, the less able it is to distinguish between the two documents.

$$Score_{TI} = \frac{\sum_{i=0}^{K} w_{i,d} \times w_{i,q}}{\sqrt{\sum_{i=0}^{K} w_{i,d}^2} \times \sqrt{\sum_{i=0}^{K} w_{i,q}^2}}$$

The weights for the terms in the index are computed according to formula $w_{i,d} = f_{i,d} \times \log \frac{N}{n_i}$, where $f_{i,d}$ is the normalized frequency of term *i* in document *d*. The weights for the query terms are computed using the formula $w_{i,q} = \left(0.5 + \frac{0.5 freq_{i,q}}{\max_l freq_{l,q}}\right) \times \log \frac{N}{n_i}$, where $freq_{i,q}$ is the raw frequency of term *i* in the query.

2.3 Partitioned TF-IDF (PTI)

The degree of similarity between the retrieved concept maps and the query is computed from a vector representation of the concept maps similar to the term-frequency vector with inverse-document frequency adjustment (TF-IDF) (Baeza-Yates and Ribeiro-Neto 1999) but that also considers the unique structure of the map. It adjusts weights according to the distance of the concepts to the top concept and the number of outgoing and incoming links to a concept (Leake, Maguitman et al. 2003). Using TF-IDF adjusted by the number of links, a keyword that appears in a concept that has no outgoing or incoming links will have zero weight. From the search perspective, all keywords that appear in the concept map must have a weight greater than zero. Thus, the number of outgoing and incoming links for every concept is increased by one. Then, the weight of keyword *i* in map c_d is computed as:

$$Score_{PTI} = \frac{\sum_{i=0}^{K} w_{i,d}}{\sqrt{\sum_{i=0}^{K} w_{i,d}^2}} \text{ where } w_{i,d} = (n + m + 1) * \sqrt{1/(h+1)}$$

In the formulas above, *n* is the number of incoming links, *m* the number of outgoing links and *h* is the number of steps between the concept that contains the keyword and the top concept of the map. A slight adjustment is made to include the keywords of the title of the concept map in the computation. The number of steps from any concept to the top concept is increased by 1, so that the title is positioned at level 0 (as if it were the top concept), the top concept at level 1, and so on. The scoring function for the PTI ranking method is identical to the TI method, where each query term weight is 1.

2.4 Concept Distance (CD)

For each retrieved concept map, the degree of similarity is computed by analyzing the proximity of the search terms in the concept map. The distance is zero if both terms appear in the label of a concept; otherwise, the distance is the shortest of all possible paths that exist from a concept that contains a search term to the concept that contains the another search term. The system computes the relevance of the concept map *j* as:

$$Score_{CD} = 1 \Big/ n * \sum_{i=0}^{n} 1/(d_i + 1)$$

In the formula above, *n* is the total number of pairs of terms and *d* is the minimum number of steps between the terms of the pair *i* in the concept map *j*. In this algorithm, the title of the concept map is also treated as a top concept, so that keywords from the title are weighted and considered in the similarity computation of the map as well.

2.5 Combined PTI-CD

The combined PTI-CD ranking method computes a simple weighted sum of the PTI and CD scores. The motivation for this is that the PTI and CD methods involve complementary methods of using the concept

map structure to influence the search result ranking. By combining the two methods, we expect the resulting performance to be better than PTI alone. Since CD requires more than one search term to be used, it cannot be used by itself, but must be combined with another method capable of single term queries.

3 Experimental Setup

To test our hypothesis that the new ranking algorithms would improve the rate at which relevant documents are presented in the top 5 results, we conducted an experiment aimed at determining how effectively search ranks the results of CmapTools searches.

The motivation for the experiment is that CmapTools users often remember seeing particular pieces of information while browsing through hyperlinked concept maps, but may not have a convenient way to retrieve that information. The CmapTools search ranking algorithms should aid the user in finding this information if they accurately reflect the relevance of concept maps to the search query. If the map containing the recalled information is ranked high in the result set following the query, the ranking measure is considered accurate. If it is not, then it is considered inaccurate. Our principal question is "What is the performance of the current CmapTools ranking algorithm?" Our secondary question is "Can changes in the ranking method provide better results?"

3.1 Method

3.1.1 Data preparation

We constructed a data set based on the concept maps that were stored on the IHMC Internal CmapServer as of Jun 2006. From this server, we removed all documents that were written in a language other than English, were protected by a username and password, or were not concept maps. We then created a search index for this data set that computed and stored the weights associated with the different ranking methods in the index.

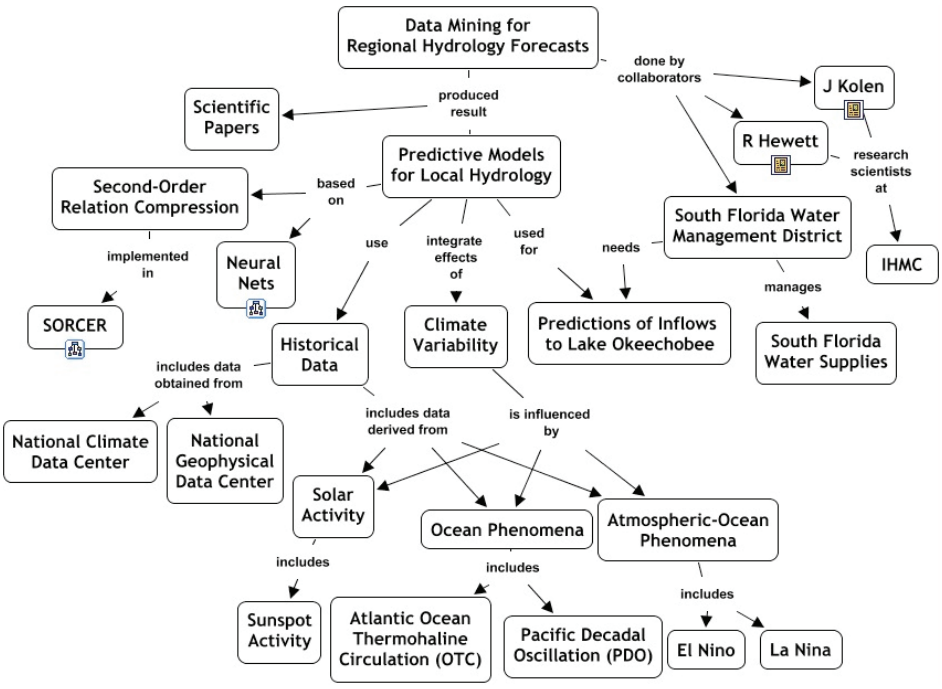


Figure 1. Example concept map typical of those used in the ranking study.

As part of the indexing process, we randomly selected 20 maps for potential use as targets. Of these, we found 10 that were well-constructed concept maps. The maps that were not selected generally had defects such as being entirely composed of unlabeled concepts ("????" in CmapTools), having three or fewer concepts, or being entirely disconnected.

3.1.1.1 Question generation

Eight people volunteered to participate in this experiment. Subjects were asked to examine each concept map in the test set and to write down two questions whose answers can be found in the map. An example map used in this experiment is shown in Figure 3.

We asked subjects for two questions to avoid having only the obvious "What is <root concept>?" types of questions. Many subjects asked this question, but then asked a more relevant question as their second attempt. When subjects did ask the "What is <root concept>?" question, it was removed from the test set, as virtually all algorithms perform very well on this type of query. We also discarded non-responsive and duplicate questions, leaving 98 queries out of a possible 160.

3.1.1.2 Query generation

After the questions were selected, each was converted into a query. This was done by eliminating stop words and connectives. Table 1 shows some examples of typical questions and their corresponding queries.

Subject Question	Search Query
What is Regional Hydrology Forecasts?	regional hydrology forecasts
How can you predict Local Hydrology?	predict local hydrology
What are uses of predictive models?	uses predictive models
What are the current results from data mining for regional hydrology forecasts?	current results data mining regional hydrology forecasts
How can data mining aid the construction of predictive models for local hydrology?	data mining aid construction predictive models local hydrology
How can we build predictive Hydrology Models?	build predictive hydrology models
What does Data Mining for Regional Hydrology Forecasts do?	data mining regional hydrology forecasts

Table 1. Converting questions to queries.

3.2 Evaluation Criteria

Each of the queries was run seven times, once with each ranking method. The results were recorded to a data file, which was subsequently analyzed.

The resulting data file indicated where the concept map that was used to generate the question for the search query appeared in the list of search results. Ideally, the map would appear very high in the search results, within the first five results (which is the number of results visible in the CmapTools Search dialog.)

While it is typical to report ranking experiments in terms of "precision" and "recall" – the number of relevant retrieved document and the number of relevant document retrieved, respectively – this would have required our test subjects to rank the relevance of all results retrieved, or to use a specially constructed data set. Since we wanted to test our algorithms on "live" data, either of these solutions would require a level of effort beyond the resources available for this work. Therefore, we report our results in terms of the position in which the map corresponding to the query appears in the search result list.

4 Results

The data collected from the four ranking methods are shown in Figures 4 and 5. Figure 4 shows how many times the example map was found in the first five positions (<5) of the search result list, the fifth through tenth positions (<10), and so on. The performance of the PTI ranking method was particularly

surprising – being the lowest performing algorithm of the group - as a similar method has proven very effective in clustering concept maps (Leake, Maguitman et al. 2003). **Figure 2** shows the cumulative percentage of example maps found over the same rank location bins as Figure 4. It is interesting to compare the convex shape of the curves for the KW and TI ranking methods with the concave shape of the curves for the PTI (75-25), CD, and PTI methods.

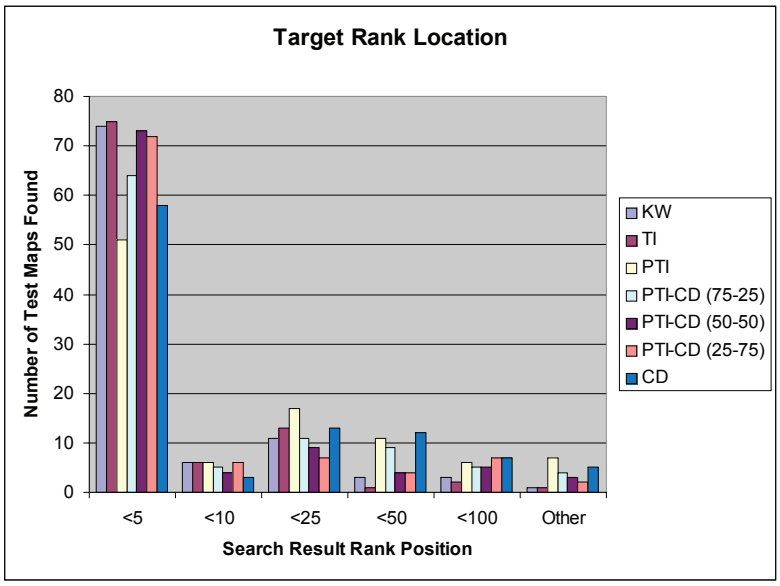


Figure 3. Number of example maps found in each rank position.

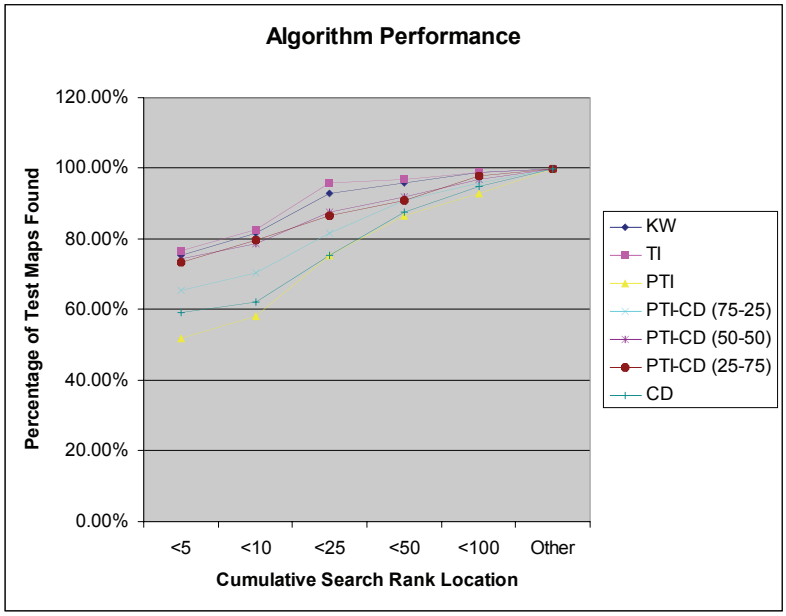


Figure 2. Cumulative percentage of example maps found by rank position.

5 Discussion and Future Work

The results of this experiment countered the intuitions of the authors. We initially expected virtually all of the algorithms to be as good as or better than the KW algorithm. However, the results show that the KW

and TI algorithms perform better than the remainder of the algorithms. We initially expected that the PTI algorithm, especially when combined with the CD algorithm would be the best performer of the lot. Our thinking was that because PTI computed TF-IDF based on location in the concept map, it would allow the search to distinguish between maps that contain concepts as central terms versus those that incidentally mention those concepts. However, individually PTI and CD had the worst performance of the group. Interestingly, the 50-50 and 25-75 combinations of PTI and CD performed significantly better than the two algorithms individually. In future work, we will explore this connection further, and also experiment with the addition of CD data to the KW and TI algorithms. Because of the hierarchical structure of concept maps, the information provided by CD, while not enough to rank results on its own, may provide the extra bit of discrimination necessary to move above 75% of results in the top 5 search rank locations.

Further analysis of the KW algorithm has shown that much of its accuracy comes from the small bonus awarded for finding the keyword in the title of the concept map. Removing this bonus results in the percentage of example maps found in the first five positions falling from 75.51% (74/98) to 58.16% (57/98) making it's performance on par with PTI and CD. This suggests that weighting *where* the keywords are found may be a good way of increasing overall accuracy of any of the algorithms.

This again points to the intuition that the PTI algorithm should be more effective than its performance indicated in this experiment. One reason for this lack of performance may have been that this experiment addressed finding a *particular* map rather than a wide ranging set of maps on a particular subject. On a more broadly evaluated search, the PTI algorithm may do better. Therefore, evaluation of our future experiments will include looking at the top maps found and evaluating the algorithms based on their relevance to the query. For example, even though the map corresponding to the test query was found in location 5, it does not mean that the results in locations 0-4 are erroneous or less relevant. They may be even more relevant than the map used to generate the query. This testing will require considerably more effort that our current experimental methodology, but the benefits of experimentally determining the "optimal" concept map ranking algorithm will extend to the entire CmapTools community.

6 Acknowledgements

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References

Baeza-Yates, R. and B. Ribeiro-Neto (1999). Modern information retrieval. Harlow, England, Addison-Wesley.

Cañas, A. J., G. Hill, et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain, Universidad Pública de Navarra.

Coffey, J. W., T. C. Eskridge, et al. (2004). A Case Study in Knowledge Elicitation for Institutional Memory Preservation Using Concept Maps. Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain, Universidad Pública de Navarra.

Leake, D. B., A. Maguitman, et al. (2003). Topic Extraction and Extension to Support Concept Mapping. Proceedings of FLAIRS-2003, AAAI Press.

Novak, J. D. (1998). Learning, creating, and using knowledge : concept maps as facilitative tools in schools and corporations. Mahwah, N.J., L. Erlbaum Associates.

Novak, J. D. and D. B. Gowin (1984). Learning how to learn. Cambridge Cambridgeshire ; New York, Cambridge University Press.

Salton, G. and M. J. McGill (1989). Introduction to Modern Information Retrieval. New York, McGraw-Hill Book Co.

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READING NATURE FROM A BOTTOM-UP PERSPECTIVE

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Abstract This paper reports on a study of ecology teaching and learning in a Swedish primary school class, (age 10-11yrs). A teaching sequence was designed aiming at helping the students to *read nature* in a river ecosystem. The teaching sequence had a bottom up approach in the sense that it took its starting point on a common key organism- the freshwater shrimp. From this species and its ecology the perspective was broadened to involve studies of the interrelations between organisms and finally to the relation between the biotic and abiotic factors. A large part of the instruction took place outdoors. The main objective for the study was to follow students developing ecological understanding. Each student was interviewed early, in the middle and late in the teaching sequence. The interviews were semi-structured and resembled the construction of a concept map. Students were asked to describe and link a large number of objects on a tray. The objects related to the river ecosystem and comprised a large number of living organisms together with non living objects such as water, air and pictures of the sun and of humans. The task for the student was to identify the objects and to describe the ecosystem by linking them up in as many relevant ways as possible and explain their reason for the linking. These tray interviews were translated by the researchers to concept maps which graphically represent the researchers' interpretation of the interviews. Concept maps together with a revised SOLO-taxonomy are used to illustrate students developing ability to read nature. Results indicate how students relate several abstract processes and correlations back to the key organism studied early in the teaching sequence.

1 Introduction

The ability to *read nature* is central in this work and has been described in another paper (Magntorn & Helldén 2005) but needs a brief explanation here as well. We see it as an important aspect of ecological literacy where ecology is seen as a scientific field with a tendency to amalgamate with other disciplines and form interdisciplinary fields such as environmental education. The phrase ecological literacy is a re-conceptualisation of the phrase *environmental literacy* which Orr (1992) refined to *ecological literacy*. According to Orr ecological literacy primarily constitutes "knowing, caring and practical competence" and . "How people and societies relate to each other and to natural systems, and how they might do so sustainably". Ecological literacy is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment which lead to ecological sustainability. Returning to our phrase *reading nature* we see this ability as an important aspect of ecological literacy. Its focus is on ecology and the context is outdoors. This literacy has to do with an ability to recognise organisms and relate them to material cycling and energy flow in the specific habitat which is to be read. It has to do with the natural world that we face outside and the tools we have are our experiences from previous learning situations both in and out-of-doors.

The ecosystem to be read is a river and we have followed a year 4 class (age 10-11 yrs) when they studied the ecosystem. Together with the teacher we have designed a teaching sequence spanning 7 lessons from February till May where most of the teaching was conducted outdoors. The teaching sequence had a bottom-up design where we started with focussing on the fresh water shrimp and a few other common organisms in the river. Finding and naming the organisms together with close studies of their morphology and their adaptations to life in running water was followed by studies of their interactions directly or indirectly with the other components, both biotic and abiotic, of the ecosystem.

2 Objectives

In this project there are two main objectives. The first objective has a methodological approach where we present a type of interviews resembling the construction of a concept map. Students are asked to link living and non-living objects from the river in as many ways as possible. All the objects are presented on a large tray and students are asked to use a hierarchical structure when they link their objects to an ecosystem as in a concept map. Students' "tray interviews" have been interpreted by the authors as concept maps illustrating students' ability to read nature. The other objective has to do with students' learning and how they can relate their ecological understanding of a key stone species to the understanding of the function of the ecosystem.

3 Background

Research on students learning and understanding of ecology suggests that developing an understanding of ecosystems and their functioning is difficult. Leach and colleagues did a cross sectional study of 5-16 year old students and their understanding in ecology and they found that student ideas of the function of the ecosystem is not seen as an interrelated whole, i.e., photosynthesis, respiration and decay are not viewed as cycling of matter in ecosystems (Leach et al. 1996). A review of the literature suggests that students do not have a good grasp of the complexity in food webs, of energy flow or of the dynamics and structure of ecosystems (e.g. Adeniyi, 1985; Gallegos et al, 1994; Hogan & Fisherkeller 1996; Grotzer & Bell Basca 2003). Studies have also found that students often find ecology education as cut off from real life and not appealing to them since they are not familiar with the species and dynamics presented (e.g. Magro et al 2001). With the bottom-up design young students' knowledge of organisms and how they live in their environment is central and when Lock et al. (1995) asked a sample of 12-14 what sort of living things they would expect to find in freshwater frogs, tadpoles and fish were commonly mentioned but few made reference to plants or invertebrates. Other studies have shown that students have great difficulty in the classification of invertebrates (e.g. Kattman 2001). Since many of the invertebrates found in a river are larvae becoming flying adults it is also important to know the difficulties young students have with life cycles where they tend to forget the egg stage and the cyclicity of the life stages (Shepardson 2002).

4 Research design and methodology

Important for our research design has been Ausubel's theory of meaningful learning (Ausubel, 1978) supplemented by Novak (1998) who stresses the importance of the interplay taking place between emotions, personal relevance and context when people learn. The one who is learning is actively extending her existing concepts or defining new ones. This also means finding new connections between those already given and the new ones as well as finding new structures and sustainable theories. When meaningful learning occurs, the relationship between concepts become more explicit, more precise and better integrated with other concepts and propositions. This involves what Ausubel calls *progressive differentiation* of conceptual and propositional meanings, resulting in more precise and/or more elaborate ideas. In our study a relevant example might be the understanding of the role of the sun developing from being restricted to a source of light and heat, to after instruction also being the energy source for all the living organisms in the river.

We believe, supported by e.g. Duit, Treagust and Mansfield (1996), that interviews can give reliable information about students´ ideas. We have positive experience from older students i.e. university students and secondary school students making their own concept maps on ecological topics but with younger students concept mapping can be too difficult and time consuming (Kinchin 2000). Therefore we designed a new interview method, the tray interview, based on ideas from Mellgren (2004) where students make a kind of concept map by linking a number of given objects on a large tray. They were asked to describe each object and to link it with as many other objects as possible and explain how they were related. The objects on the tray were real objects from the river such as a large number of different living invertebrates, representing herbivores, decomposers and carnivores, and both the adult and larval stages of dragonflies. There were also live aquatic plants and brown half-eaten leaves together with a picture of a salmon. Non living components were represented as gravel and rocks from the river bottom together with a glass of water, a dish with air (representing air or oxygen or carbon dioxide) and a picture of the sun and of a human.

Our impression is that the students generally find these interviews challenging as if they were a game, and their motivation for solving the task is high. Each student was interviewed early, in the middle of and after the teaching sequence (see figure 1). Each interview has been analysed by the researchers and interpreted as concept maps. This graphical illustration of students' development has been supplemented with an analysis of the interview according to the SOLO-taxonomy (Biggs & Collis, 1982).

Concept mapping with its graphical structure has been recognised as a powerful tool for helping students understand the notion of complex models such as ecosystems (Kinchin, 2000) and research has shown the importance of getting acquainted with the concept maps in order to make them a useful metacognitive tool for the learning pupil (Novak, 1998). Although these graphic representations can reveal the complex webs of students' ideas, when ideas are taken out of the context of students' wordings and reduced to conceptual labels the labels become

open to a variety of interpretations and meanings that may not accurately represent the meanings or richness of students' ideas. This is why the tray interview with possible immediate follow up questions can reduce this limitation. Research has also found that students often find it difficult to make this concept maps and that the difficulties not necessarily have to do with their understanding of the topic studied but rather that the instrument suits some students better than others (Schmid & Telaro, 1990). For the younger students we believe the advantage of an "oral" concept map is even greater than with the older students.

5 The teaching sequence and data collection in outline

The teaching was carried out in a Swedish year 3-4 class of 23 students aged 10-11. The school is a public school in a middle class community and the 23 students ranged from high to low achieving. It is important to say that the instruction was conducted by a teacher from the local nature school together with the ordinary class teacher. All the interviews were conducted by one of the researchers. There was continuous negotiation between the researchers and the teachers about the content and the design of the teaching sequence. The river, where all the outdoor teaching took place, is situated on walking distance from the school. The overall teaching sequence comprised 4 phases spanning 7 lessons of varied duration from 80 to 200 minutes (see figure 1). Space constraints make it necessary to present details of the sequence as a short synopsis.

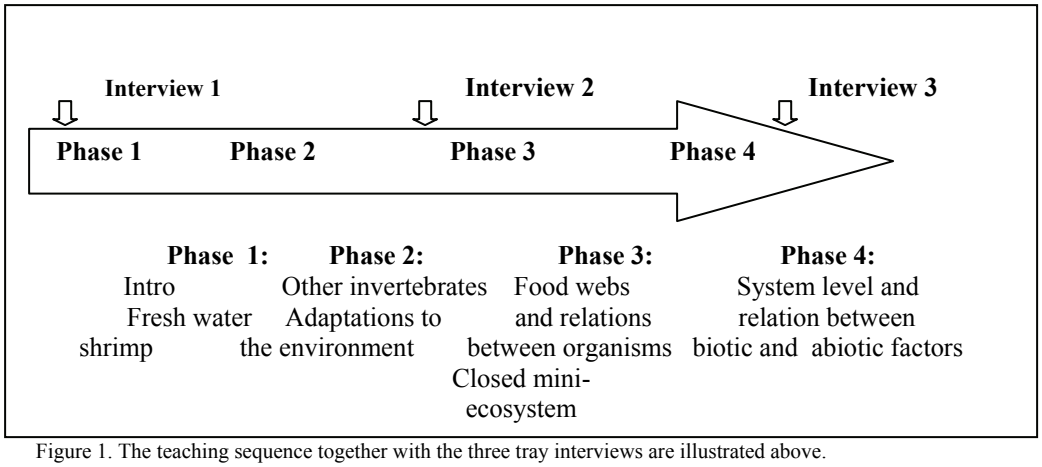


Figure 1. The teaching sequence together with the three tray interviews are illustrated above.

Phase 1: Autecology (i.e. the ecological relationships of a particular plant or animal species) of the freshwater shrimp. After having collected them in the river they studied them thoroughly and discussed their autecology.

Phase 2: Taxonomy and autecology of different invertebrates. The children collected different organisms in fast and in slow sections of the stream, studied their adaptations to the environment and the taxonomy of the different organisms. Herbivores and predators were determined according to their morphology and behaviour i.e. large eyes, large mouth parts and rapid animals are often predators. Life cycles were discussed and sealed ecosystems were constructed and discussed according to the roles of plants animals and abiotic factors such as light and air.

Phase 3: Students were introduced to food webs and food pyramids and related these models to the organisms observed in the river. Synecology (i.e. the ecological relationships of a community) was discussed. A litterbag experiment was conducted where the children put fresh water shrimps (Gammarus sp.) and water louse (Asellus sp.) in small net-bags together with green and brown leaves. The bag was then put into the river and after a week it was collected and studied in order to find out that the animals preferred brown leaves and could be considered decomposers in the ecosystem.

Phase 4: Systemic view of the ecosystem was discussed where students were introduced to photosynthesis and energy flow in the ecosystem. The relation between abiotic and biotic factors were discussed and investigated focussing on the importance of high water flow for aeration of the water and the importance of trees both for the main food source and for the shadow keeping water temperature low and subsequently oxygen level higher. The

importance of a varied bottom substrate for a higher diversity of life was discussed together with the direct and indirect human impact on the river ecosystem.

In conclusion the teaching started of with the taxonomy (naming) of the common species and particularly the freshwater shrimp and its autecology. This was followed by the autecology and life cycles of the common invertebrates and synecological models were introduced such as food chains and food pyramids. Finally a systemic view of the ecosystem was discussed where the biotic and abiotic factors were linked in many different ways. Reading nature has to do with recognition of the authentic structures and objects in the ecosystem and the ability to link taxonomy, aut- and synecology to a systemic view.

6 Framework according to SOLO

The SOLO taxonomy (Dart & Boulton-Lewis 1998; Biggs & Collis 1982), was designed to be particularly relevant to school and university learning environments, with the central feature being a focus on the structure of students' responses after a teaching sequence. It offers a model for characterizing levels of sophistication of children's developing explanations, and it was used as our basis for the analysis of the children's tray interviews. The principles on which explanations were assigned to the various levels mainly hinge around the sophistication of causal notions between structures, such as plants, animals and non-living objects, and functions in the ecosystem. The SOLO taxonomy focuses on sophistication and does not necessarily equate with conventional scientific ideas. Hence, we have added an aspect of correctness to our definition of the five SOLO levels regarding the ability to read the river ecosystem. The levels of our revised SOLO taxonomy are described below. They are developed in direct relation to the topic- reading nature. This ability is related to age and experiences and, of course, a biologist reads nature differently to a primary school student. Our levels are adapted to a concrete symbolic mode where a person thinks by the use of a symbol system such as written language or number systems. Thinking in this mode requires a real world referent. This is the most common mode addressed in learning in the upper primary and secondary school. The levels are also directly related to the aim of the teaching sequence and distinctions between the levels are made from the analysis of student interviews. The teaching sequence is designed to start with

1. **Prestructural.** The responses are often inadequate and the student is frequently referring to irrelevant aspects. Species knowledge is non-existent or very limited. The autecological (i.e. the ecological relationships of a particular plant or animal species) relations are trivial single step relations such as fish need water to swim in or all animals need the sun to be able to see. No synecological (i.e. the ecological relationships of a community) relations are described. No functional aspects describing the key processes of photosynthesis, cycles of matter and flow of energy is mentioned.

2. **Unistructural**. Single aspects of the task are picked up, but the task itself is not attacked in an appropriate way. The student is reasoning in the relevant mode but only single step relations without any mediating description of a sequence of causally linked events or relations. Species knowledge covers a handful of common organisms. The autecological relations are often single step relevant relations, in the first hand, describing the freshwater shrimp and its features such as feeding, breathing and reproduction. No synecological relations are described. No functional aspects describing the key processes of photosynthesis, cycles of matter and flow of energy is mentioned. This level of explanation indicates fragmentary understanding without any attempt to make a synthesis or systemic analysis of the ecosystem.

3. Often all the items are involved but only in one step relations but the objects can have single relations to more than one object.

4. **Multistructural**. Causal chains are given in the explanations, linking two or more objects together and referring to relevant ecological theory. There is no attempt, however, to raise the explanations and linking to the level of a generalization. Species knowledge covers at least the seven most common organisms. The autecological relations are often single step relevant relations, but also chains of relations involving organisms on several trophical levels (i.e. levels in the food web). Adaptations to water flow are mentioned. Life cycles of some of organisms are described but without linking to ecological effects. No functional aspects describing the key processes of photosynthesis, cycles of matter and flow of energy are mentioned. No process discussions or abstract relations are discussed.

5. **Relational**. Relational explanations extend relevant points to a general principle, or interrelationship between factors. Species knowledge covers at least the seven most common organisms. Autecological relations of organisms belonging to different trophical levels are supplemented with the synecological principles of a food pyramid. Other synecological relations described are the life cycles of some organisms and its effect on the ecosystem over the whole year. The sun is often mentioned early in the interviews. Students do not relate to abiotic factors or human influence on the river on a systems level. Plants growth depending on light and producing oxygen is mentioned and energy in the form of food in the food web is often discussed but no discussion about cycles of matter and no synthesis about these processes are made.
   Different life cycles are discussed.

6. **Extended Abstract**. The coherent whole is generalised to a higher level of abstraction. The students discuss ecology as in the relational level but also refer abstract relationships between biotic and abiotic factors such as photosynthesis or human effect on the ecosystem such as the morphology of the river banks, light conditions and pollutants. Species knowledge covers at least the most common organisms. Autecological relations of organisms belonging to different trophical levels are supplemented with the synecological principles of a food pyramid. Other synecological relations described are the life cycles of some organisms and its effect on the ecosystem over the whole year. Students give more than one explanation or cause for processes in the ecosystem and they can refer to feed back causality in ecosystems such as the importance of both decomposers and plants. Autecology about a few key species can be referred to ecological principles which are linked. "The salmon is actually containing old dead leaves since they eat animals which have eaten leaves" Generally mentioning how the flow of energy and cycling of matter occurs in the river as well as in other ecosystems.

7 Results and analysis

According to our revised SOLO-taxonomy we can see a strong development over the course (see figure 2.) The diagram illustrates how most student have a very limited ability to read nature prior to instruction. Most students in the second interview can relate to the autecology of the freshwater shrimp and the life cycles and adaptations to water flow of many of the invertebrates but they have difficulties relating the facts to a whole.

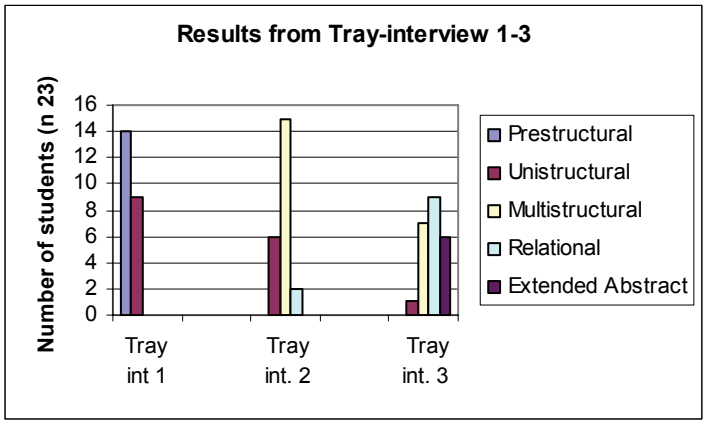


Figure 2. The diagram illustrates students' SOLO levels in tray interviews 1-3.

In the third interview students still start by describing the freshwater shrimp and its autecology but they often add synecological and systemic relations. 15 students can read the river on at least a relational level where they link the organisms to the function of the ecosystem. The diagram gives a very superficial illustration of students' development and we have therefore chosen to include the concept maps from the three interviews of one of the students, Anna. The teacher with 30 years of teaching experience describes Lisa as "an average student, quite lazy but she is good at logical thinking".

In the first interview, prior to instruction, student's ability to read nature was very limited. The relations between items on the tray were often single step and trivial. Species knowledge was with a few exceptions restricted to fish, dragonfly and molluscs. This is different from similar studies on terrestrial ecosystems where f.ex. bugs, butterflies and spiders often are recognised by young students (Hogan & Fisherkeller 1996, Shepardson 2002). Having names for the common organisms is an important part of reading nature.

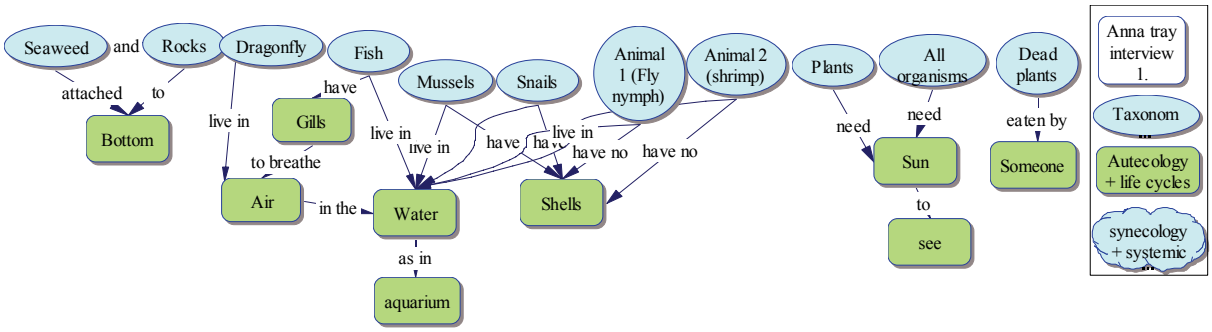


Figure 3. Anna's tray interview 1. The concept map contains concepts marked with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and (cloud) systemic and synecological level. She was categorized as prestructural according to our revised SOLO-taxonomy.

Our experience together with many other researchers is that students often refer to personal experiences of ecological processes in terrestrial ecosystems such as earth worms turning dead leaves to soil (Hogan & Fisherkeller 1996, Helldén 1995) or they discuss food chain relations between predators and prey i.e. who eats who. This kind of reasoning often relates to episodic memories (White 1988) which are important for linking experience with relevant propositions and intellectual skills. In the first interview Anna only recognised dragonflies, mussels, snails and seaweed. She related the mussel and the snail because they both had shells. The dragonfly was linked to air since it flied and the plants to the gravel since they lived in gravel. Sun gave light for seeing and water was to live in and fish had gills to breathe and she said they breathe air as in an aquarium. Her reading of the ecosystem is poor and it seems that without proper names for the organisms and without knowledge of their autecology Anna cannot describe the ecosystem and generalise about processes in nature. References to episodic memories of relevant experiences prior to instruction were almost absent. She was categorized as prestructural according to our SOLO-taxonomy.

Prior to the second interview students had been catching and studying the freshwater shrimp and collected animals in the fast and slow streams. Naming and adaptations together with life cycles were what most students discussed in the second tray interview. The shrimp was naturally the key organism and most students discussed its feeding and its morphology and adaptations to a life in the river. Many students had names for several animals and now they could discuss their abundance and their roles in the ecosystem but no discussion took place on a systemic level including abiotic factors or cycles and flow. Knowledge about a few animals, particularly the shrimp, and practical experience of catching and studying the animals help all students to discuss the ecosystem on a taxonomic and autecological level. Anna was focusing on the freshwater shrimp and related autecological concepts and also synecological links between plants and freshwater shrimps. Most students including Anna were categorized as multistructural according to our revised SOLO-taxonomy.

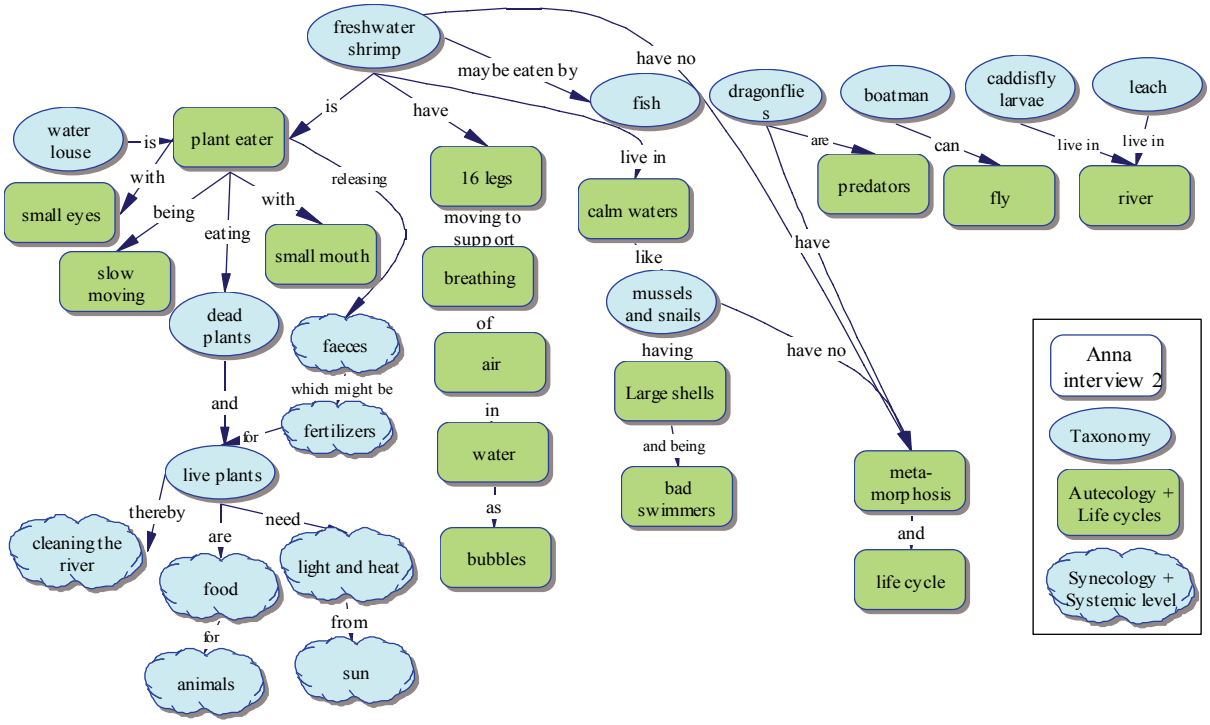


Figure 4. Anna's tray interview 2. The concept map contains concepts marked with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and (cloud) systemic and synecological level. The freshwater shrimp is her starting point and she relates it to several autecological features.

In the third interview students had experienced feeding experiments, models of food chains and food pyramids related to the animals found in the river. Photosynthesis and oxygen production was discussed together with a discussion about human impact on the river and how one can measure the water quality according to biological parameters. As in interview 2, most students started by describing the shrimp. Some still focused on the taxonomic level where they knew the species names but relevant systemic reasoning was absent or poor and they did not reach further than the multistructural level. Most students, though, linked the organisms to their habitat and related them to abiotic factors such as oxygen and light and referred to the whole ecosystem. Anna could recall the names of many of the organisms but most of all she had a systemic view on the ecosystem and included the photosynthesis and bacteria and anoxic conditions. Anna interpreted what she had experienced over the whole course and she generalised her understanding to the river ecosystem but also to general ecology in any ecosystem. She is categorized as extended abstract according to our revised SOLO-taxonomy. In her tray interview (Figure 5) she referred to several of the episodes (episodic memories are marked with a * in the concept map) during the teaching sequence. These episodes together with the taxonomy and autecology of the organisms seem to be her way of constructing an ability to read nature.

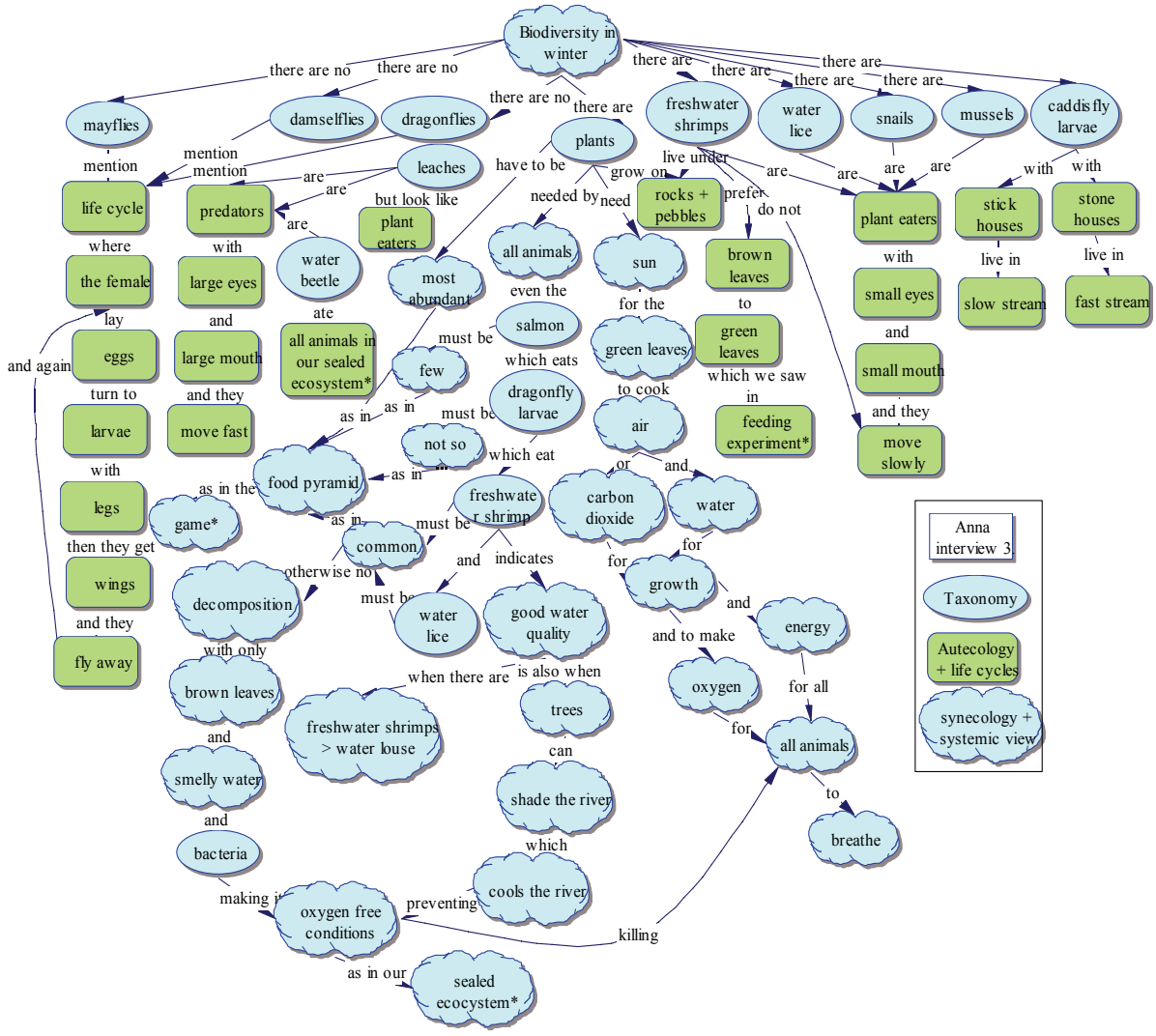


Figure 5. Anna's tray interview 3. The concept map contains concepts marked with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and (cloud) systemic and synecological level. Concept marked with an * refer to episodes during instruction.

8 Summary

Developing an understanding of ecosystems and their functioning is difficult (Leach et al. 1996) and students often find the theory abstract and not related to real examples from nature which students can relate to (Magro et al. 2001). In this project we have implemented a teaching sequence focusing on a key stone species, a freshwater shrimp, and tried to build an ecosystem understanding based on the ecology of this organism. We have found that the recognition of one species and the knowledge of its autecology is helpful for the students when they discuss the whole ecosystem functioning. A majority of the students can relate the freshwater shrimp to systemic levels of ecosystems understanding. Memorable events such as outdoor activities and challenging experiments seem to be important for the meaningful retention of knowledge since many of the students often refer to these when they read nature. In this study we have also found the tray interviews to be very fruitful for eliciting students understanding of the ecosystem functioning and its parts -whole relation. The resemblance to concept map construction with its metacognitive component has been important and since the young students do it orally it eliminates the sometimes tiresome writing. Tray interviews have been interpreted by the researchers to concept maps which have been analysed in relation to the SOLO-taxonomy which we find to be a promising way of analysing students' ability to read the river ecosystem.

9 References

Adeniyi, E. O., (1985) Misconceptions of selected ecological concepts held by some Nigerian students. Journal of Biological Education, 19, 311-316.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978) Educational Psychology: A cognitive view. New York: Holt Rinehart & Winston

Biggs,J & Collis, K. (1982) *Evaluating the quality of learning: The SOLO Taxonomy* New York Academic Press.

Duit, R.,Treagust, D. & Mansfield, H. (1996) Investigating student understanding as a prerequisite to improving teaching and learning in science and mathematics. In D Treagust, R,Duit & B, Fraser (Eds) *Improving Teaching and Learning in Science and Mathematics* pp 17-31. New York Teacher College Press.

Gallegos, L., Jerezano, M., E. & Flores, F. (1994) *Preconceptions and relations used by children in the construction of food chains*. Journal of Research in Science Teaching, 31, 259-272.

Grotzer, T., A. & Basca, B., (2003) *How does grasping the underlying causal structures of ecosystems impact students' understanding?* Journal of Biological Education 38 (1) 16-29

Helldén, G. (1995) Environmental Education and Pupils' Conceptions of Matter. Environmental Education Research., 3 267-277.

Hogan, K., Fisherkeller, J. (1996) *Representing students thinking about nutrient cycling in ecosystems*. Journal of Research in Science Teaching, 33 (9) 129-141.

Kattman,U., (2001) Aquatics, Flyers, Creepers and terrestrials – students conceptions of animal classification Journal of Biological Education 35 (3)

Kinchin I., M. (2000) *Concept mapping in biology*. Journal of biological Education, 34 pp61-68.

Leach, J., Driver,R., Scott, P. & Wood-Robinson, C. (1996) *Childrens ideas about ecology 2: ideas found in children aged 5-16 about the cycling of matter.* International Journal of Science education, 18 (1), 19-34.

Lock, R. (1998) Fieldwork in the life sciences. *International Journal of Science Education*. 20 (6) 633-642.

Magntorn, O., & Helldén, G. (2005) Student-Teachers' Ability to Read Nature: Reflections on their own learning in ecology. *International Journal of Science Education* 27 (10) 1229-1254.

Magntorn, O., & Helldén, G. (in press) Reading New Environments: Students' ability to generalise their understanding between different ecosystems.

Magro, A., Simmoneaux, L., Navarre, A. & Hemptinne, J-L. (2001) *The teaching of ecology in the agricultural secondary curricula in France: a new didactic approach*. In Proceedings of the III Conference of European researchers in Didactics of Biology. September 27-October 2. Santiago de Compostela 197-205.

Mellgren, I. (2004) Brickan som en resurs i undervisningen. (Tray as a resource in education) Bi-lagan. Nationellt resurscentrum för biologi och bioteknik. No 3.Uppsala University, Sweden.

Novak, J. D. (1998) *Learning, creating and using knowledge*. Mawhah, NJ: Lawrence Erlbaum Associates.

Orr, D.W. (1992) *Ecological Literacy: education and the transition to a postmodern world* (Albany State University of New York)

Shepardson, D.P.(2002) Bugs, butterflies and spiders: children's understanding about insects. *International Journal of Science Education* 24 (6) pp. 627-643.

Schmid, R. F & Telaro, G.(1990) Concept mapping as an Instructional Strategy for High School Biology. *Journal of Educational research* vol.84 nr 2 78-85.

White, R. T. (1991) Episodes and the purpose and conduct of practical work. In B.E. Woolough (ed.) *Practical Science*. Milton Keynes: Open University Press.

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RE-EXAMINING THE FOUNDATIONS FOR EFFECTIVE USE OF CONCEPT MAPS

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Abstract. The use of concept maps continues to grow worldwide, and users are consistently finding new applications and uses for the tool. However, we continue to observe difficulties in the use of the tool that seem to be consistent throughout countries and domains of use. Among them, we cite the difficulty in the construction and structure of propositions, the lack of a focus question to guide the construction of the map, and the tendency to construct descriptive as opposed to explanatory concept maps. In this paper we examine how an understanding of the foundations of concept mapping and the ability to ask good questions can aid in addressing these problems, resulting in a more effective use of concept maps.

1 Introduction

There are today many different applications for what we call concept maps, and many of these applications are substantially different from the uses when this tool was first developed in 1972. Moreover, the advance of computer technology and the development of the Internet have conferred new capabilities for the use of this tool. We thought it would be useful to re-examine the foundations for this tool and to discuss implications for current and future applications. Many of the difficulties we observe with the use of concept maps derive at least in part from inappropriate use of the tool, lack of adequate training for users and trainers, and a general failure to recognize the importance of the theoretical foundations for the tool. We shall begin with a discussion of some of the difficulties we see in the use of concept maps, review of important theoretical ideas and then move to a discussion of various applications, illustrating how the concept mapping tool might be used more effectively.

2 Difficulties

Even though concept mapping today is used in ways and in domains that we would not have been able to predict years ago, the main purpose of the concept map continues to be the same: it is a tool that allows one or more persons to represent explicitly their understanding of a domain of knowledge; and the theoretical foundations of concept mapping haven't changed.

However, as we see the use of the tool in different places, some difficulties seem to be pervasive.

1. The construction and structure of propositions seems to be a problem that many concept mappers have.
2. The lack of a (good) focus question that 'focuses' the construction of the concept map;
3. Concept maps tend to be mostly descriptive as opposed to explanatory, with many of them being classificatory.

We believe that some of these issues can be addressed by (a) a clear understanding of the foundations, and (b) asking good questions, including the focus question that triggers the construction of map, the questions that teachers use to prompt the students to improve their maps, the questions that map constructors ask themselves while building the maps (which lead to refining and expanding the map and construction of other maps), the questions that students ask each other when collaborating, or the questions that knowledge engineers ask experts while eliciting knowledge. We first re-examine the theoretical foundations and later discuss the topic of questions.

3 Re-examining the Foundations

Concept mapping, as we use this term, derived from a research project where first and second grade children were taught basic science concepts, and interviewed periodically over the twelve-year span of their schooling to determine how this early instruction influenced later learning of science (Novak, 2005; Novak & Musonda, 1991). Novak and his team tried various assessment strategies to monitor children's learning, including the use of modified

Piagetian clinical interviews (Pines & Novak, 1978). While the interviews did reveal striking differences in children's understanding of the science they were being taught, it was difficult to track specific changes in each child's concepts of matter, energy, and other concepts that were taught. Novak's team reviewed in depth the Ausubelian learning principles and also the constructivist epistemological ideas underlying their work. The latter theoretical works also were foundations for the audio-tutorial science lessons developed and interviewing strategies that were employed.

Briefly, the key epistemological ideas considered were: (1) The universe consists of objects and events, and energy exchanges during events. (2) Concepts are constructed by humans and are perceived regularities or patterns in events of objects, or records of events or objects, designated by a label, usually a word. (3) Two or more concepts can be linked with appropriate words to form a meaningful statement or proposition. (4) Concepts and propositions are the building blocks of knowledge in all fields. The key learning principles that were considered, based on Ausubel's (1963; 1968) cognitive psychology were: (1) *Meaningful learning* (as contrasted with *rote* learning) is necessary for development of conceptual understanding. Meaningful learning is sometimes characterized as *deep* or *dynamic* learning, (in contrast with *surface* or *static* learning). (2) New learning must build on relevant prior concepts and propositions held by the learner. (3) The learner must be encouraged to choose to learn meaningfully. (4) Appropriate concrete props are needed to learn abstract concepts, together with appropriate didactic instruction. (5) Learning is highly idiosyncratic and progresses over time. (6) High quality meaningful learning leads to construction of well integrated concept and propositional structures (i.e. cognitive structures) that better facilitate new learning and creative problem solving. Given these foundational ideas, Novak's groups sought to represent knowledge as a hierarchical structure of concepts and propositions, a form they called a concept map.

Figure 1 shows an example of a concept map that illustrates the key ideas described above. Note that objects or things are key building blocks of the universe, and they are also key building block of knowledge. We use words, usually nouns, to label objects. *Events* are the other key building blocks of the universe, and also for knowledge. When we focus on events, we are usually asking how something happens, and concept maps emphasizing events, using verbs, and they tend to be richer in explanations, whereas concept maps focused on objects tend to be more

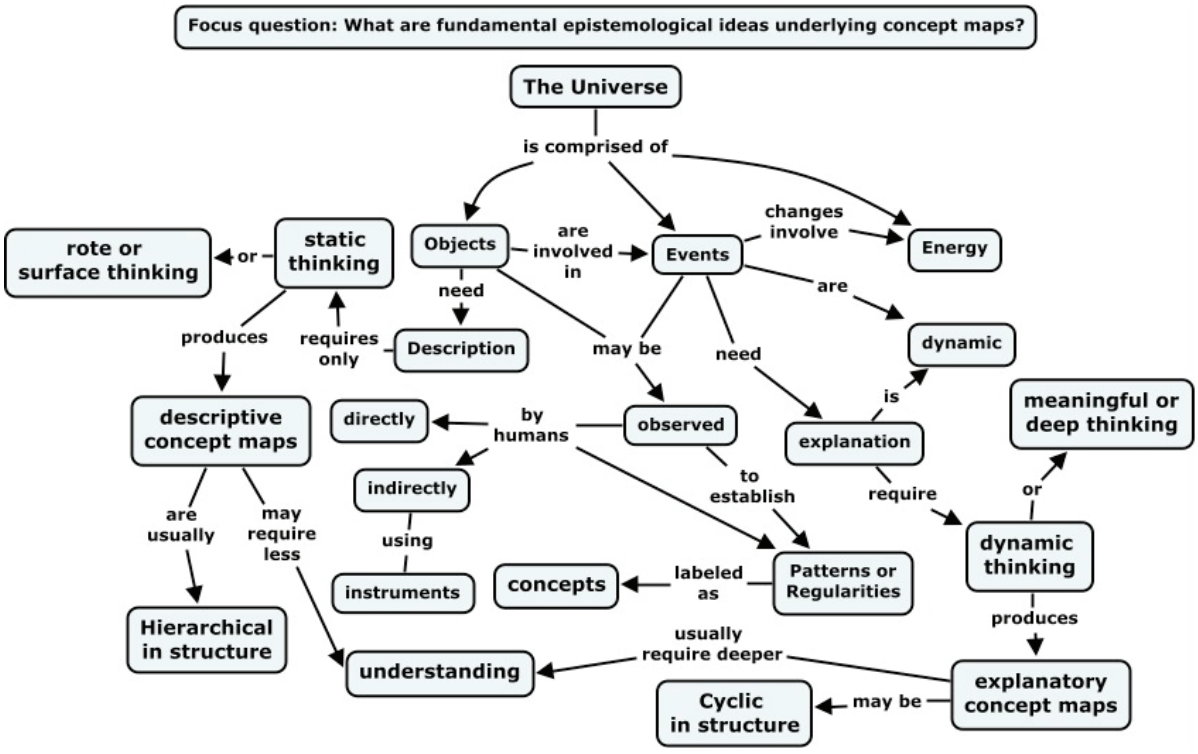


Figure 1. A concept map showing the key theoretical ideas underlying construction and use of concept maps.

descriptive. In general, concept maps showing explanations require more deep or dynamic thinking. We have observed, however, that most concept maps deal with objects, not with events, and propose that through the proper focus question, and through questioning in general, we could move towards the dynamic thinking that is required to build concept maps showing explanations.

4 The Importance of Questions

Unfortunately, concept maps are frequently used only as an assessment tool. As a result, students have 'one shot' at getting the concept map right, either in a test or as an assignment. In our New Model of Education (Novak & Cañas, 2004) we propose a concept-map centered learning environment (Cañas & Novak, 2005) where the concept map is used from the beginning of a unit to determine how much a student knew beforehand, through the unit as a means for researching and linking resources found or created by the student, until the map shows at the end how much the student has learned about the topic. Within this environment, the concept map evolves as the student learns, reflecting his/her increased understanding, and its through questions from the teacher, from colleagues, or questions that the student asks him/herself that the student pursues a deeper understanding that is reflected in the map.

4.1 The Focus Question(s)

A good way to define the context for a concept map is to construct a *Focus Question*, that is a question that clearly specifies the problem or issue the concept map should help to resolve. Every concept map responds to a focus question, and a good focus question can lead to a much richer concept map, as will be examined later. When learning to construct concept maps, learners tend to deviate from the focus question and build a concept map that may be related to the domain, but which does not answer the question. This is fine in the sense that the map built probably answers another focus question, and so the focus question of the map should be changed to reflect this (CmapTools provides a field for the focus question as part of the information that is stored with a Cmap, and the focus question is displayed in the header of the window when a map is displayed, making the focus question explicit to the viewer). In the case of a school-learning environment, it may be important to have the learner go back and construct a concept map that responds the original focus question. However, its important to clarify that starting with a single focus question does not imply that the 'job is done' when that question is answered. Fagundes and Dutra (2006) emphasize in their work with teachers and students the importance of questioning each individual concept in a concept map (do I understand what this concept really means and its relationship with its linked concepts?) This leads to research and searching, and to the generation of focus questions for other concept maps that will end up linked to the original map.

4.2 Asking Students Questions

As a student is building a concept map, the teacher should probe the student to (a) find out how much the student knows about the topic, and (b) help the student improve, refine or expand the concept map. Unfortunately, there is little research on question-asking during concept map construction. Chacón (2006) has reported on the "pedagogical question" and its use as a mediating instrument during concept map construction. She refers to three moments during the construction of concept maps (a) defining the context, where she proposes that questions be asked that help determine the context, such as "Why are we addressing this problem?", "Why use concept maps to solve this problem?", "Where do we find information?" among others; (b) development of the concept map, where the focus question is constructed, inquiry questions such as 'where? what? who?' help establish what the student(s) already know (see the section below on Interviewing), verification questions are used to verify whether propositions in the concept map are true or not and if they are coherent or not, amplifying questions to find out if information is missing or concepts need to be expanded and cross links added; (c) reviewing purpose, where through questions the student can take cognizance over how he/she is building his/her Cmap. Not coincidentally, Chacón (2004) has done a large portion of her work with pre-school children, and it's in papers on the use of concept mapping in pre-school where the authors, including Chacón, have reported the questions-answer dialogues that have lead to the construction of concept maps by children (see for example, Beirute, Brenes, Cortés, García, & Meza, 2006; Cassata & French, 2006; Mancinelli, 2006; Mancinelli, Gentili, Priori, & Valitutti, 2004). Authors working with preschool children all emphasize the importance of teachers asking questions instead of providing the students the 'right' answers. We could all benefit from paying attention to the way these teachers lead their students in the process of improving their

concept map construction through careful questioning. Learning to ask question requires training, and we have found that one way to learn how to ask questions is through learning how to interview, as is described below.

4.3 Learning to Ask Questions: the Interviewing Experience

Learning to interview requires that one listen carefully to what the interviewee is saying. Teachers are notoriously poor at this and tend to steer students to answers, or just give them answers, rather than probe the child's mind and listen carefully to what they are saying. Concept mapping the interview plays an important role in the process.

During the process of developing the concept mapping tool, there was a constant interplay between the structuring of interviews, transcribing interviews, and creation of concept maps from the interviews. This interplay is critically important to understanding and constructing good concept maps. Therefore we recommend that all users of this tool engage early in their practice to conduct several interviews and proceed to construct concept maps from these interviews. Detailed procedures for this can be found in Novak and Gowin (1984, Chapter 7). It should be recognized that we are trying to probe into a person's cognitive structure and ascertain what concepts and propositions that person has relevant to a particular topic and how are these integrated and organized? This is a profoundly challenging task, and yet it is fundamental to improving teaching and learning in any field. It is also essential for the capture and archiving of expert knowledge, an application of concept mapping that is growing rapidly. We will illustrate the process using two interviews with children dealing with plants in our lecture. The interviews were conducted as part of the planning for an elementary school program dealing with plants with the acronym LEAP (LEarning About Plants). The program was developed by staff of Cornell University Plantations.

Planning an interview begins with identifying one or a few Focus Questions that will be the main interest of the interviews. Then a concept map should be prepared that anticipates the kind of knowledge that might be revealed and organizes the ideas for the interview. In general, this concept map will be more comprehensive than that drawn from interviews, since the interviewer has to be prepared for all possible answers. The objective is to understand what prior knowledge children typical of this age group will bring to the lessons to help with planning the lessons. It should be noted that this concept map used to guide interviews might need to be modified as interviewing progresses, and also the interview may need to be modified until it can be "standardized". This is an iterative process, but our experience has been that two or three cycles of prepare map-interview-map student-revise interview are sufficient for a given target audience on a given topic.

We will show brief video clips of two children being interviewed, one a third grader and the other a fourth grader. These interviews began with questions about "what is a seed", and then moved to "what do seeds and plants need to grow"? It is common with interviews that one may begin with a given Focus Question, and as the interview proceeds, another focus question may emerge. The interviews done some years ago by one of Novak's graduate students will illustrate good interviewing techniques, including position of the interviewer, sufficient "wait time" after a question is asked, and neutral feedback that does not steer the interviewee's answers. We found that both children are not aware of the role of carbon dioxide in plant growth, do not know that seeds are formed in the ripened ovaries of flowers, and in general appear to have little or no understanding of photosynthesis. However, both have significant knowledge about seeds and how they grow into plants, so there is a good conceptual foundation for building their understanding further with appropriate instruction. Interestingly, the younger child actually has an important concept the fourth grade child lacks, namely the idea that sun is needed for plants to grow. Both children correctly indicate that plants need minerals from the soil to grow. The interviews and the concept maps we prepared identify explicitly new concepts that need to be learned, such as the fact that the sun is a source of energy and energy is needed to make food from water and carbon dioxide. However, the missing concepts also suggest that these children lack an understanding of the concepts of energy, atoms, molecules, gas, and liquid. Some level of development of these concepts would be needed for the children to understand the process of photosynthesis. The latter concepts were developed in some depth in The World of Science Program (Novak, Meister, Knox, & Sullivan, 1966).

It is to be expected that any given interview protocol will lead to new questions to be explored. For example, the above interview suggested that students had a pretty fuzzy knowledge of how plants use sun to produce food. This could lead to another interview on this focus question. It is likely that the new interview would show that students do not understand the nature of gases such as oxygen and carbon dioxide, and an interview on this subject would likely

show that they also lack an understanding of the particulate nature of matter, including the nature of atoms and molecules. We found this to be the case in our work as we planned our 12-year longitudinal study, and for this reason, the lessons we prepared for grades one and two placed heavy emphasis on developing these concepts. Contrary to popular opinion in the 1970's, we were able to show that students could at least begin to understand these concepts and that this influenced future science learning.

Becoming skilled at probing into learner's cognitive structure is a profoundly challenging task, and yet it is fundamental for understanding how learners learn. It also helps build skills in asking good questions and guiding the students to ask good questions. Developing interviewing skills and skill in concept mapping interviews should be part of every teacher-training program. A typical problem teachers have is that they do not wait long enough for students to respond after they ask a question. Rowe (1974) and others have found that on average teachers wait only 0.7 second before they answer the question, ask a different question, or move to another student for a response. This short wait time does not permit the deep cognitive processing that is needed for a learner to generate a good response. Interviewing can help a teacher to see that the "wait-time" after asking a question might need to be 10-30 seconds or more to obtain thoughtful responses from the student. Longer wait-times are especially needed when questions are asked that require explanation, rather than simply naming an object or event.

One of the uses of CmapTools that is growing in importance is the capture and archiving of expert knowledge. For corporations, knowledge is in most cases the principal asset of the company, and too often when workers retire or leave, much of this asset is lost. Another problem is that precious corporate knowledge was archived in various company reports, consisting primarily of texts and data tables. Such knowledge is notoriously difficult to retrieve by others, who might benefit from this knowledge, and most corporations find that current or new employees seldom read these archived reports. Capturing expert knowledge from people is fundamentally a process of becoming skillful in interviewing corporate workers. At IHMC, we have been involved in a series of projects to train workers in the use of concept maps for capturing and archiving knowledge.

4.4 Questions among Students: Collaboration

CmapTools was designed with the purpose of facilitating collaboration (Cañas *et al.*, 2004). Within this collaboration framework, the software provides for students to easily collaborate in building a concept map. They can either work on a given map at the same time, i.e., synchronously, or at different times as their schedules permit (asynchronous collaboration). Vygotsky (1978) stressed the importance of social exchange in learning, especially with learners who are at about the same Zone of Proximal Development (ZPD). That is, students who are at about the same level of cognitive development (same ZPD) on a given topic will enhance each other's learning if they engage in active exchange of ideas. Using the collaboration tools in CmapTools can facilitate this exchange.

The software includes features that allow teachers and/or students to ask each other questions. The "Annotation tool" is a 'post-it note'-type of annotation by which students can post short comments or questions on other students' concept maps. CmapTools provides for an 'annotate permission' on servers that allow students to annotate each other's concept maps without having the permission to modify them. Discussion threads (DTs) provide threaded discussions that can be attached to any concept or linking phrases. Through DTs students and teachers can get involved in more in-depth discussions than in an Annotation. CmapTools also provides the possibility of collaborating at the knowledge level through Knowledge Soups (Cañas *et al.*, 2001), whereby collaborating students publish propositions (called 'claims' in this environment) to a Soup, and in return are displayed claims from other students that are similar to the ones they published (see Figure 2). However, students can question each others' claims by attaching a discussion thread to them (as shown in Figure 2), and students are expected to defend the claims they published (Cañas, Ford, Brennan, Reichherzer, & Hayes, 1995).

In a previous research effort the Knowledge Soups had a 'Giant[1]' (Reichherzer, Cañas, Ford, & Hayes, 1998, August). This tool took propositions from the Soup and generated questions and propositions of its own that it presented to the student. For example, if a proposition published by one student was "green plants make food" and another claim was "plants use sunlight to make food", The Giant might ask, "do green plants use sunlight?". Students would teach the Giant by telling him whether the question was true, false or silly. If The Giant asked, "does

[1] CmapTools does not currently incorporate an implementation of the Giant.

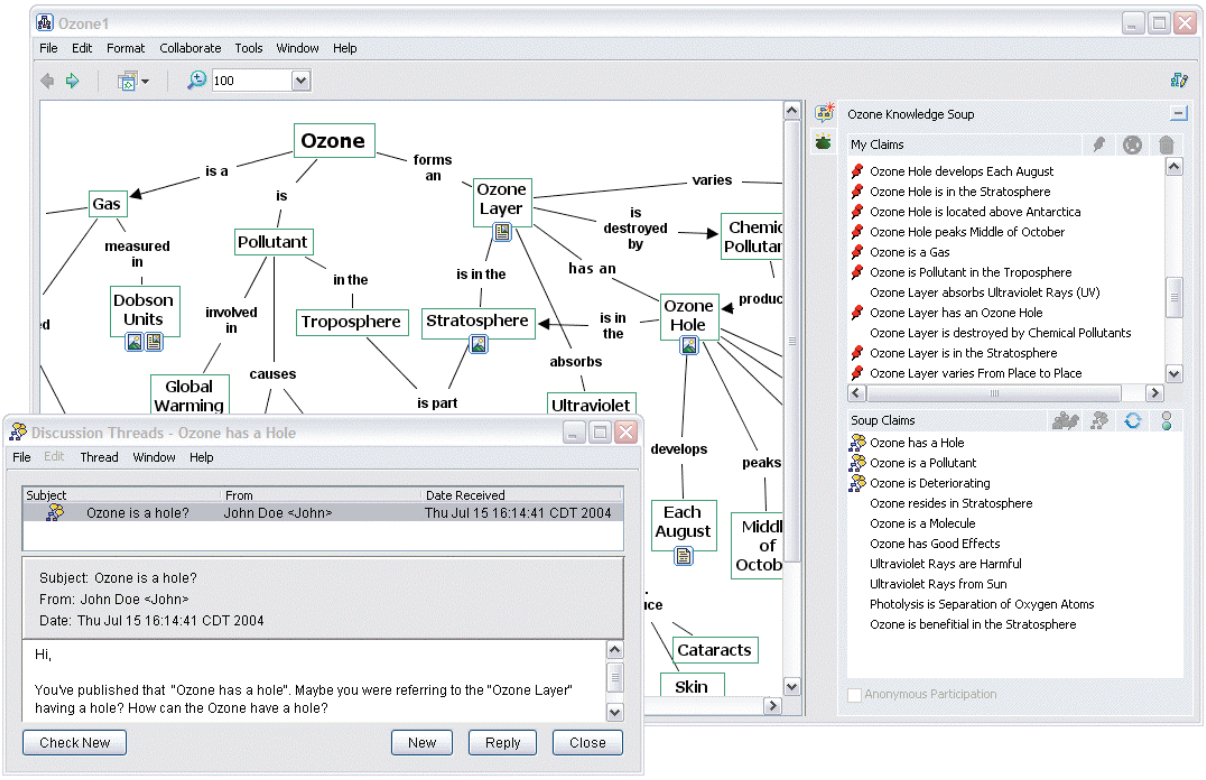


Figure 2: Students collaborate through a Knowledge Soup on the Ozone and question each other through Discussion Threads in CmapTools.

sunlight make green plants?", this would be marked as silly. The Giant was not an intelligent tool, and therefore the recombination of concepts and propositions made by the Giant were often nonsense. Nevertheless, the questions asked often stimulated enhancement of the concept maps and some good discussion among collaborating students.

5 Dynamic Verses Static Knowledge

Earlier in this paper we commented on the need to move towards the dynamic thinking that is required to build concept maps showing explanations, that is, concept maps that deal with *events* as opposed to *objects*. Cause and effect diagrams (also known as Ishikawa, fishbone, or characteristic diagrams) and causal maps are specialized graphs that depict the factors that contribute to or affect a given situation: all the causes, that is, that lead to a certain effect. However, these maps suffer from the same representation restriction as mind maps, having no linking phrases that clearly and explicitly explain the relationship between the events, or in other instances have been formalized to the point that they are no longer amenable to be used by children but are meant for computers to understand.

In a series of studies, Safayeni, Derbentseva and Cañas (2005) have found that the structure of concept maps can be indicative of the level of thinking expressed in the map. For example, concept maps modeled with a circular structure (see Figures 3 and 4) lead to significantly more instances of meaningful or dynamic propositions when compared with concept maps modeled with a tree-like structure. In work presented at the Concept Mapping conferences (Derbentseva, Safayeni, & Cañas, 2004, 2006) they further report on experiments comparing two strategies to encourage the construction of more dynamic relationships: the use of quantifiers on the root concept of a concept map and a dynamic focus question. Interestingly, although a more dynamic focus question has an effect on the nature of the propositions generated, it is adding a "quantifier" to the root map that has the greatest impact. Although the results of the experiments are preliminary, they report on three methods by which more dynamic thinking can be encouraged: cyclic maps, a dynamic focus question and a quantified root concept.

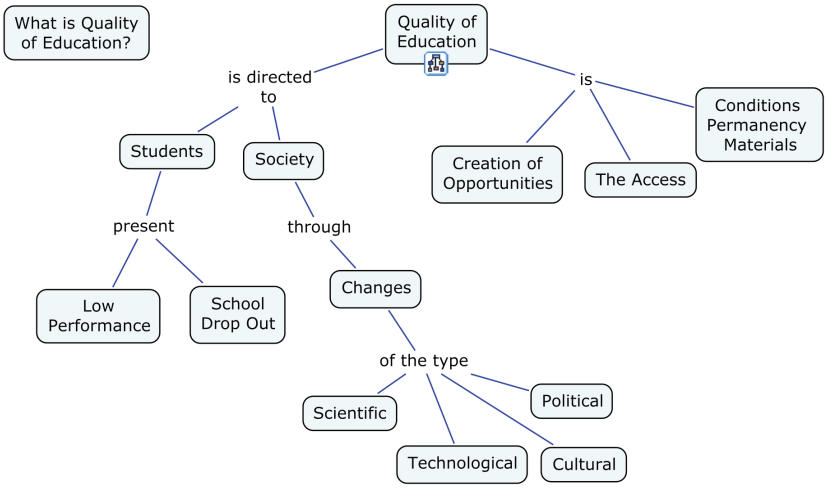


Figure 3. Tree-structure concept map generated from a static focus question.

We have started applying these ideas in our work with concept mappers, and have found that although a more dynamic focus question can generate a more dynamic map, concept mappers often ignore the question's nature and construct a declarative concept map. Adding a "quantifier" to the root concept, as reported above, tends to force the mapper to generate a more dynamic set of propositions. This is shown in two concept maps on the topic "Quality of Education" constructed by teachers during workshops, where the concept map in Figure 3 was constructed from the focus question "What is Quality of Education?" and was not given a root concept, resulting in a declarative type map, and Figure 4 was constructed from the Focus Question "What are the Effects of an Increase on the Quality of Education?" and a root concept of "Increase in Quality of Education" (an event), resulting in an interesting cyclic map based on dynamic propositions.

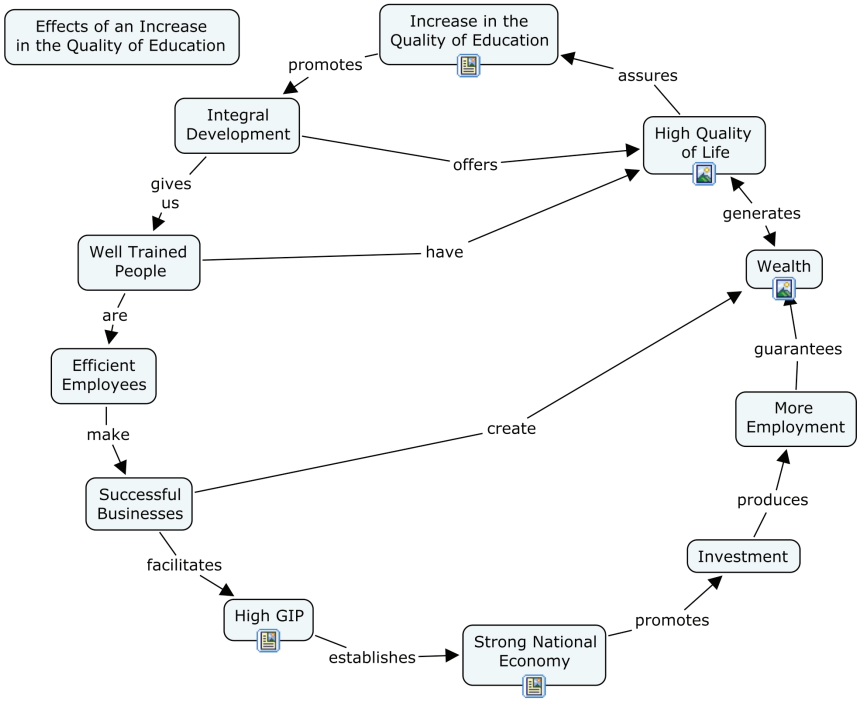


Figure 4. Cyclic concept map generated from a dynamic focus question and a quantified root concept.

The studies by Safayeni and colleagues serve to illustrate how much we have yet to learn about strategies for optimizing the use of concept maps for the encouragement of high levels of dynamic or meaningful learning. Their work also serves to illustrate the importance of constructing and using good focus questions. This has long been recognized, and it is one reason why CmapTools calls for the inclusion of a Focus question whenever a concept map is saved. Unfortunately, we often see that concept mappers fail to construct a focus question in advance of building a concept map, or they simply ignore the question as their map construction progresses.

6 Conclusions

Effective education programs provide for a wide range of learning activities including selected readings, Internet searches, project work, report preparation and presentation, drawings, video presentations, collaborative research, and other activities. With CmapTools, it is possible to develop a general concept map to serve as a framework for guiding these studies and as a tool to integrate all other learning activities into one highly organized *knowledge model*. These knowledge models can be shared with others, stored on a server, and used as an "archive", that can serve as a starting point for future studies. In this concept map-centered environment, the concept map evolves from an initial 'assessment' of what students know about the topic being studied to a knowledge model reflecting the students' progress. The extent to which the constructing concept maps help the student improve their understanding depends, to a large extent, on the quality and type of maps they build. Good questions, whether they come from the teacher, other students, or the concept mapper questioning him/herself, lead to better maps, a more dynamic thinking, and a deeper understanding. We would like to see more systematic research on this issue and encourage participants at this Conference to include research questions dealing with the nature and quality of questions and their effects on map properties and value for learning.

7 References

Ausubel, D. P. (1963). *The Psychology of Meaningful Verbal Learning*. New York: Grune and Stratton.

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Beirute, L., Brenes, M., Cortés, G., García, S., & Meza, A. (2006). La Contrucción de Mapas Conceptuales en Edad Preescolar. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San Jose, Costa Rica: Universidad de Costa Rica.

Cañas, A. J., Ford, K. M., Brennan, J., Reichherzer, T., & Hayes, P. (1995). *Knowledge Construction and Sharing in Quorum.* Paper presented at the Seventh World Conference on Artificial Intelligence in Education, Washington DC.

Cañas, A. J., Ford, K. M., Novak, J. D., Hayes, P., Reichherzer, T., & Suri, N. (2001). Online Concept Maps: Enhancing Collaborative Learning by Using Technology with Concept Maps. *The Science Teacher, 68*(4), 49-51.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Cañas, A. J., & Novak, J. D. (2005). *A Concept Map-Centered Learning Environment.* Paper presented at the Symposium at the 11th Biennial Conference of the European Association for Research in Learning and Instruction (EARLI), Cyprus.

Cassata, A. E., & French, L. (2006). Using Concept Mapping to Facilitate Metacognitive Control in Preschool Children. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San Jose, Costa Rica: Universidad de Costa Rica.

Chacón, S. (2006). La Pregunta Pedagógica Instrumento de Mediación en la Elaboración de Mapas Conceptuales. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San José, Costa Rica: Universidad de Costa Rica.

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2004). Experiments on the Effect of Map Structure and Concept Quantification during Concept Map Construction. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology, Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2006). Two Strategies for Encouraging Functional Relationships in Concept Maps. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San Jose, Costa Rica: Universidad de Costa Rica.

Fagundes, L., & Dutra, I. (2006). Personal communication.

Mancinelli, C. (2006). Learning While Having Fun: Conceptualization Itineraries in Kindergarten Children Experiences with C-Maps in an Italian School. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the Second International Conference on Concept Mapping*. San Jose, Costa Rica: Universidad de Costa Rica.

Mancinelli, C., Gentili, M., Priori, G., & Valitutti, G. (2004). Concept Maps in Kindergarten. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Novak, J. D. (2005). Results and implications of a 12-year Longitudinal Study of Science Concept Learning. *Science Education, 35*(1), 23-40.

Novak, J. D., & Cañas, A. J. (2004). Building on Constructivist Ideas and CmapTools to Create a New Model for Education. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the 1st International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York, NY: Cambridge University Press.

Novak, J. D., Meister, M., Knox, W. W., & Sullivan, D. W. (1966). *The World of Science Series. Books One through Six*. Indianapolis, IN: Bobbs-Merrill.

Novak, J. D., & Musonda, D. (1991). A Twelve-Year Longitudinal Study of Science Concept Learning. *American Educational Research Journal, 28*(1), 117-153.

Pines, A. L., & Novak, J. D. (1979). *Scientific Concept Learning in Children with Audio-tutorial Instruction: The Effect of Prior Knowledge on Resulting Cognitive Structure*. Ithaca, NY: Cornell University, Department of Education.

Reichherzer, T., Cañas, A. J., Ford, K. M., & Hayes, P. (1998, August). *The Giant: A Classroom Collaborator.* Paper presented at the Proceedings of the Workshop on Pedogogical Agents, San Antonio, TX.

Rowe, M. B. (1974). Wait-time and Rewards as Instructional Variables: The Influence of learning, logic and fate control. Part 1. Wait Time. *Journal of Research in Science Teaching, 11*(2), 81-94.

Safayeni, F., Derbentseva, N., & Cañas, A. J. (2005). A Theoretical Note on Concept Maps and the Need for Cyclic Concept Maps. *Journal of Research in Science Teaching, 42*(7), 741-766.

Vygotsky, L. (1978). *Mind in Society: the Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

REFLEXIONES TEÓRICAS PARA LA IMPLEMENTACIÓN DE ESTRATEGIAS METODOLÓGICAS QUE FACILITEN LA CONSTRUCCIÓN DE MAPAS CONCEPTUALES "PROFUNDOS"

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Resumen. *Quienes hemos trabajado capacitando a personas de diversas edades en la construcción de mapas conceptuales, podemos compartir la experiencia de que las personas pasan por una serie de etapas en su intento de hacer mapas cada vez más significativos. Además, en la experiencia de trabajo con mapas conceptuales con niños en edad preescolar las observaciones reflejan una interesante correspondencia entre la elaboración de tipos de mapas y la etapa del desarrollo cognitivo en que se encuentra el niño.*
En el presente trabajo, se parte de una síntesis sobre las teorías que subyacen a los mapas conceptuales (constructivismo de Piaget y Aprendizaje Significativo de Ausubel) con el objetivo de ofrecer elementos que permitan la comprensión de los procesos lógicos del pensamiento y su relación con el diseño de diferentes tipos de mapas. Se ofrecen criterios para el diseño de metodologías de enseñanza sobre construcción de mapas conceptuales contribuyendo con los docentes en resolver sus inquietudes en cómo estimular el diseño de buenos mapas.

1 Antecedentes

Los mapas conceptuales son la representación gráfica del estado del conocimiento de un sujeto o grupo, en un momento dado. Es una herramienta gráfica para organizar y representar conocimiento (Novak y Cañas, 2006).

Los mapas conceptuales reflejan la estructura cognitiva del individuo, es decir, reflejan la forma en que el sujeto o grupo establece relaciones entre diferentes conceptos relevantes en un dominio dado. Refleja entonces la forma de relacionar y también la forma de relacionarse (Beirute, 2002). Fundamentado en el Constructivismo (Piaget, 1969) y el Aprendizaje Significativo de Ausubel y Novak (1978), propone un modelo gráfico para representar el proceso de construcción del conocimiento.

Si bien no hay investigaciones sistemáticas que confirmen ***el patrón de relaciones seguido por las personas para la elaboración de un mapa,*** sí puede confirmarse en la práctica, la necesidad de docentes y capacitadores de desarrollar metodologías que estimulen esos procesos de construcción. El objetivo de la presente propuesta, es ofrecer un espacio de reflexión para diseñar investigaciones que ofrezcan luces sobre:

- -la relación entre la estructura cognitiva y la elaboración de mapas conceptuales,
- -los estadios de desarrollo cognitivo y los procesos lógicos presentes en la construcción de mapas,
- -diseño de estrategias para estimular la construcción de mejores mapas (aquellos que expresen relaciones más significativas), es decir estrategias pedagógicas que promuevan la construcción de "mapas más profundos".

2 Consideraciones teóricas

El proceso de construcción del conocimiento requiere de estrategias directamente relacionadas con los procesos de construcción del pensamiento lógico. Si los mapas conceptuales reflejan la organización de la estructura cognitiva, es de suponer que en su elaboración, los sujetos utilicen las estrategias del pensamiento lógico.

¿Cuáles son las etapas del pensamiento lógico que están presentes en el momento de construir un mapa?

A efectos de ofrecer material teórico que oriente la respuesta a esta pregunta, nos atrevemos a proponer una síntesis de la génesis del pensamiento, basado en los aportes de Jean Piaget y de algunos investigadores que han realizado estudios sobre las propuestas piagetanas acerca de la construcción del pensamiento lógico-matemático (Beirute, 1995; Maldonado G., 1996). El material se resume en una tabla en la que se establece la secuencia de esos procesos mentales.

2.1 El conocimiento lógico: establecido según las etapas del desarrollo del pensamiento del niño en las etapas preconceptual y operatoria

Esquemas: (representaciones mentales) **en las etapas pre-conceptuales** →	**Procesos mentales** que se originan en la relación del niño con los objetos	**Conductas que reflejan la presencia de procesos mentales propios del pensamiento lógico** →
1. Permanencia del objeto: estructura previa que es más que memoria, e implica el descubrimiento de que los objetos son permanentes y no meras prolongaciones del niño. (Piaget, 1969)	El niño puede establecer relaciones simétricas: descubre semejanzas y diferencias entre los objetos, tomando en cuenta la presencia o ausencia de una cualidad **La clasificación y sus etapas** Clasificar es un proceso humano básico que no se reduce a la actividad matemática. Nuestra actividad clasificatoria comienza en el momento en que elaboramos los primeros conceptos; no olvidemos que un concepto, al fin y al cabo, *no es más que un conjunto de regularidades percibidas a las que se dotan de un nombre (clase) distintivo.* (Novak,2002)	Estas condiciones estimulan la aparición de dos procesos del pensamiento lógico: ♦ la clasificación y ♦ la seriación
	1-La etapa de la Colección figural: El niño va colocando objetos uno al lado del otro por semejanza.	1.1- <u>El **alineamiento**</u>: Los niños forman una especie de agrupamiento, según la presencia o ausencia de una cualidad entre varios objetos, y los ubica en un orden *lineal y generalmente vertical.* 1.2- <u>**Objetos colectivos**</u>: Esas agrupaciones en forma vertical las llegan a percibir como conformando una unidad, un conjunto. El niño realiza agrupaciones de objetos por la presencia o ausencia de cualidades semejantes, <u>pero sin ningún orden.</u>
2.Surge la presencia de un nuevo esquema mental: la **inclusión.** Implica la formación de clases (si pertenece o no a la clase). Estas relaciones Piaget las define como relaciones intensivas.	**2-La etapa de Colección no figural:** el niño forma pequeñas colecciones separadas por diferencias. Luego hace subclases. El pensamiento es aún pre-conceptual Al agrupar por clases interesa la semejanza de elementos, **pero no interesa el orden**	♦ Puede hacer pequeñas relaciones causa-efecto , con ciertas limitaciones, porque todavía no puede comprender el mundo más allá de las propiedades de los objetos, ni comprender el efecto que producen sus acciones sobre ellas. Su conocimiento es egocéntrico, privado.

3. Surge en el proceso la presencia de un nuevo esquema: **el esquema de conservación.** Esto es, descubre la presencia de una totalidad independiente de la disposición o ubicación de las partes. Es decir, supera la contaminación perceptual que se asocia a la distribución espacial de los elementos de un conjunto.	**<u>Aparece la seriación y sus etapas:</u>** Se trata de establecer un orden y una jerarquía. Interesa el orden y la cantidad en las agrupaciones El niño clasifica por cantidad. Implica la posibilidad de establecer relaciones asimétricas, lo que sugiere la capacidad para establecer diferencias extensivas. <u>Se trata de hacer comparaciones ya no entre objetos, sino entre relaciones.</u> **Seriar** es la habilidad para colocar objetos (físicos o mentales) en una determinada secuencia. Esta secuencia, normalmente viene sugerida por sus primeros términos, por tanto, el primer aspecto de la seriación es la capacidad de descubrir el criterio (s) y después hacerlo operativo completando la serie. Aplica la *noción término a término*: para cada elemento de un conjunto, existe otro elemento haciendo una correspondencia uno a uno (cardinalidad). El proceso de seriación implica poner las diferencias en forma progresiva, es un orden que se da después de haber elegido la cualidad que sirve como principio de la seriación. Ello implica utilizar el proceso mental de ordenamiento de una cualidad.	La representación de ese proceso mental se presenta a continuación: -primero alinea objetos por orden de tamaño: el niño lo realiza en forma intuitiva -luego construye series por ensayo y error al ir haciendo comparaciones entre los elementos En esta etapa del proceso de seriación: **e**l niño establece relaciones comparativas de elementos en un conjunto y las ordena por diferencias. Más tarde hace la seriación de los elementos de un conjunto y el otro lo adjudica sin seriarlo. Luego aplica la noción de *correspondencia ordinal*: no importa la disposición espacial, porque la cantidad es una condición permanente.
	Puede entonces realizar el proceso **de transitividad:** comparación seriada. Puede intercalar la ordinalidad (orden y posición) con la cardinalidad (cantidad)	Aplica los criterios de "primero" y de "último". Luego puede realizar el ordenamiento de objetos en simultaneidad creciente y decreciente y siguiendo varios criterios: tamaño, color (más grande que, menos grande que)

4.Surge el esquema de **reversibilidad**	3-Clasificación operatoria: a partir de 5 años,	♦ clasifica por semejanzas, por diferencias, por pertenencia e inclusión. ♦ utiliza más atributos y más abstractos. Agrupa colecciones por parejas y tríos (desligados de las cualidades físicas)

Cuando el niño nace no tiene conocimiento de la existencia de los objetos, posee una serie de conductas innatas (reflejos) que van ejercitándose, modificándose y coordinándose paralelamente a la actividad que el niño va desarrollando en la interacción con los objetos. Gracias a las acciones que realiza con los objetos, el niño va construyendo modelos de *acción interna*. Esto le permite llevar a cabo "experimentos mentales" con los objetos que puede manipular físicamente. El resultado de realizar tales acciones utilizando este modo interno es la esencia del pensamiento sensoriomotriz, surge así ***la acción interiorizada.*** El niño aprende primero a descubrir las características de los objetos, luego a establecer relaciones de distinto orden, luego a efectuar colecciones de objetos en base a determinados atributos.

Las operaciones mentales, antes de ser un proceso intelectual, requieren de la construcción de estructuras internas y del manejo de ciertas nociones que son ante todo, producto de la acción y relación del sujeto con objetos y otros sujetos.

El conocimiento lógico no existe por sí mismo en la realidad, ni está tampoco en los objetos mismos. Es producto de una abstracción reflexiva del sujeto.

2.2 Capacidades que favorecen el desarrollo del pensamiento lógico

Fruto de la mayor interacción social y gracias **al lenguaje** el niño descubre que sus pensamientos no son iguales a los de los demás, por lo que se irá descentrando y aprenderá que existen puntos de vista diferentes. Es por eso, que el lenguaje y la interacción social le permiten al niño *comprobar la solidez de sus intuiciones y preconceptos*, y logra identificar entonces los significantes y los significados de sus conclusiones.

2.2.1 Organización de los conocimientos sobre el mundo.

El niño organiza, es decir estructura, el conocimiento del mundo por medio de esquemas, que son representaciones mentales Estos esquemas contienen relaciones espaciales, temporales y causales. Los tipos de esquemas que articulan el conocimiento infantil según Rodrigo (2002) pueden clasificarse en tres:

1. *Escena:* los esquemas de escenas se adquieren desde muy temprano. Ya a los 2 años los niños son capaces de identificar objetos que se encuentran en sitios familiares como cocina, baño,... y rechaza aquellos que no son cosas frecuentes. A los 5 años lo hará con escenas que no son familiares (por ejemplo: ascensor).

2. *Suceso:* los niños son capaces de representar secuencias temporales entre distintos sucesos.

3. *Historias:* los niños utilizan su conocimiento del mundo cuando comprenden y recuerdan una historia, que no es otra cosa que la secuencia de eventos en un escenario determinado.

2.2.2 Formación de nociones espacio-temporales

Espacio: a través de la exploración del entorno podrán ir representando su cuerpo en el espacio circundante, reconocerán este y los objetos que se encuentran en él. Irá adquiriendo nociones de arriba-abajo, delante-detrás, dentro-fuera, cerca-lejos.

Tiempo: empieza a distinguir un ritmo temporal de acontecimientos, en el cual los que tienen lugar diariamente se suceden en secuencia. A los 3 años el pasado, presente y futuro equivale a ayer, hoy, mañana. La concepción del tiempo está ligada a los acontecimientos. El tiempo se trabaja en relación con situaciones cotidianas (antes de correr, después de dormir) o con unidades naturales (día, semana, tarde, mañana).

La clasificación , la serieación, las nociones de tiempo y de espacio, son procesos por medio de los cuales los seres humanos establecen relaciones entre los objetos y entre esas relaciones. De esta forma se estructuran los procesos de pensamiento.

2.3 El Aprendizaje Significativo. (Ausubel)

a. El aprendizaje del nuevo conocimiento depende de lo que ya se sabe. Construir el conocimiento comienza con: una observación y con el reconocimiento de eventos y objetos que ya se poseen, lo que da origen a los **conceptos.**

b. Se aprende por la **construcción de redes de conceptos**, agregando nuevos conceptos a ellas Para aprender significativamente, las personas deben relacionar un nuevo conocimiento con los conceptos relevantes que ya se conocen. El nuevo conocimiento debe de **interactuar con la estructura** de conocimiento ya existente.

c. Según Ausubel (1978) la estructura cognitiva es el conjunto de conceptos, ideas, que un individuo posee en un determinado campo del conocimiento la cual tiene una determinada organización Tiende a una organización jerárquica en relación al nivel de abstracción, generalidad e inclusividad de ideas.

d. Los conceptos tienen diferente profundidad: es decir, van de lo más general a lo específico, y se van relacionando a manera de redes. Esas redes son producto de conexiones e interacciones entre los conceptos, que se hacen a través de conceptos y proposiciones unificadoras que tienen el más amplio poder explicativo y la mayor inclusividad, o conexión con el contenido.

2.3.1 Según Ausubel hay diferentes tipos de aprendizaje:

a. El aprendizaje representacional: (etapa pre-conceptual de Piaget)

- ♦ es el más elemental, del cual dependen los otros aprendizajes
- ♦ es atribución de significados a determinados símbolos.
- ♦ es una equivalencia representacional, no es una asociación.

b. Aprendizaje de conceptos

- ♦ Conceptos: son objetos, eventos, situaciones o propiedades que posee atributos de criterios comunes y que se designan mediante algún símbolo o signos.
- ♦ Los conceptos son adquiridos por dos procesos: formación y asimilación. Por formación: los atributos de criterios (características) del concepto se adquieren a través de la experiencia directa (con diversos objetos y con otras gentes). Por asimilación: a medida que el niño amplía su vocabulario, los atributos de criterio se someten a diversas combinaciones producto del intercambio social con otros.

c. Aprendizaje de proposiciones

- ♦ Va más allá de asimilar lo que representan las palabras, implica captar el significado de las ideas expresadas en forma de proposiciones.
- ♦ Implica la relación y combinación de varias palabras, y cómo esas palabras se combinan para dar una idea que es más que la suma de esas palabras
- ♦ Tiene denotación y connotación (afectiva).

2.3.2 La dinámica del aprendizaje significativo se realiza a través de dos procesos.

a. Diferenciación progresiva: la estructura cognitiva se modifica adquiriendo nuevos significados. Ello genera una nueva jerarquización (relaciones correlativas).

b. Reconciliación Integradora: cuando las ideas ya establecidas en la estructura son reconocidas y relacionadas en el nuevo aprendizaje. Ello Implica una reorganización (implica relaciones de tipo supra-ordinario y combinatorio).

3 De la síntesis teórica a la práctica cotidiana

Si los mapas conceptuales son la representación gráfica de la estructura cognitiva, entonces los procesos de la génesis del pensamiento lógico no pueden ser ignorados en el proceso de construcción de los mapas.

La experiencia cotidiana nos advierte que las personas, independientemente de la edad, el nivel cultural, y la capacidad intelectual, generalmente presentan una secuencia más o menos similar, identificada en etapas, al realizar los primeros mapas: (nos atrevemos a describir esta secuencia basándonos en la experiencia de trabajar en procesos de capacitación para la construcción de mapas conceptuales):

-en los primeros mapas generalmente aparecen listas separadas de proposiciones, muy similares a las que los niños realizan en ***las primeras etapas de la clasificación***: es una representación lineal y vertical de ideas, con agrupaciones separadas partir de conceptos eje.

-luego las personas realizan ***representaciones "no figurales"*** en donde aparecen pequeñas colecciones de conceptos a manera de subclases a partir de enlaces de inclusión. Se agranda el mapa a partir de listas de enlaces que definen relaciones correlativas y aparecen las listas de ejemplos, como intentando confirmar las clasificaciones de conceptos que orientan hacia la construcción de clases. De ahí la forma de ramificaciones que se desprende del mapa inicial, pero que no definen todavía niveles jerárquicos de profundización y en las que los listados categoriales iniciales todavía se presentan separados.

-los aprendices descubren después de varios intentos, que las categorías de conceptos que han confirmado por pertenencia (inclusión de clases según Piaget) o exclusión, pueden reacomodarse de acuerdo a procesos de reordenamiento apareciendo las estrategias de la génesis del pensamiento lógico denominado ***seriación. En ese sentido, la primeras clasificaciones que parecían estáticas, se dinamizan y surgen reorganizaciones al interior de las clases y subclases.***

-después de "jugar" con los mapas por un proceso mediado básicamente por la intuición y por la retroalimentación que la lectura del mapa les ofrece, se orientan a establecer lo que Ausubel denomina las estrategias de la ***diferenciación progresiva,*** (en la etapa de preescolar, corresponde a la aparición del esquema de reversibilidad) Aparecen nuevas categorías conceptuales en las que de conceptos generales se desprenden relaciones más específicas y particulares. Surgen así las redes de conceptos que intentan establecerse a partir de jerarquías de inclusión Como dato interesante, es la etapa en que los docentes en su quehacer pedagógico, privilegian los mapas como estrategia pedagógica para hacer resúmenes de contenidos.

-como proceso natural en la construcción del conocimiento, surge la necesidad de compartir con otros por medio del recurso del lenguaje oral, el intercambio de ideas a partir de la conversación; con ello se genera la confirmación y legitimación de la nueva estructuración cognitiva. Es la etapa de la génesis del pensamiento cuando el lenguaje enriquece las conclusiones a partir de la integración de diferentes puntos de vista. Surge lo que Ausubel denomina el proceso de ***la reconciliación integradora en la que los enlaces cruzados y los conceptos "síntesis",*** parecieran hacer **cierres cognitivos.** Los enlaces cruzados entre conceptos en diferentes segmentos o dominios del conocimiento de un mapa, son claves para demostrar que el aprendiz entiende las relaciones entre los sub-dominios en el mapa (Novak y Cañas, 2006).

El proceso de construcción del conocimiento por medio de la herramienta de los mapas conceptuales, se va fortaleciendo por la generación de varios niveles jerárquicos y es cuando el mapa crece en profundidad. Es también el momento en que se ha realizado una nueva estructura cognitiva y por lo tanto el aprendizaje se vuelve significativo.

4 Conclusiones

Los mapas conceptuales están basados en las teorías de Piaget y de Ausubel (Novak y Cañas, 2006). Surgen como una metodología para estimular la construcción del conocimiento.

Las etapas que se siguen en la construcción de un mapa conceptual parecieran ser muy similares a las etapas de la genesis del pensamiento del niño:

1. El niño en la construcción del conocimiento, aplica en primer lugar, procesos de clasificación y formación de clases lo que requiere de relaciones por inclusión (sentido de pertenencia o no a una clase) y de relaciones entre clases (todavía sin especificar el grado de la relación).
2. Luego avanza aplicando los procesos de seriación, lo que requiere de enumeración de elementos y de relaciones de orden y correspondencia (posiciones y rangos). Interesa la especificación de la relación en términos de grado o intensidad.
3. La presencia del esquema de reversibilidad permite al niño la posibilidad de establecer nuevos tipos de relaciones: ir de la causa al efecto y del efecto a la causa.
4. El proceso de clasificación y seriación es al inicio un proceso privado, egocéntrico. Sin embargo, en ese intercambio con el medio, surge la representación simbólica, la cual nace porque la imitación interiorizada puede ser evocada en ausencia de las acciones que originariamente crearon las intuiciones. El uso del lenguaje llega a ser posible gracias a la función simbólica.

En el desarrollo de metodologías para aprender a construir mapas conceptuales, las reflexiones anteriormente descritas sugieren que:

-el aprender a construir "mapas profundos" (mapas que expresen relaciones significativas) es producto de un proceso de pensamiento lógico

-el proceso contempla las etapas en la construción categorial: (primero clasificaciones, luego seriaciones, después formación de clases, culminando con procesos de reversibilidad que facilitan la aparición de los enlaces cruzados). Estas etapas se ven concretadas en los diferentes tipos de mapas que el aprendiz (independientemente de la edad) va construyendo.

El aceptar esa secuencialidad de procesos cognoscitivos reflejada en los mapas, le permite a los docentes conocer no sólo el estado del conocimiento del tema estudiado, sino que le ofrece parámetros para diagnosticar la estructura cognitiva del aprendiz. Con esa información, el docente podrá estimular el pase a una nueva etapa cognitiva, es decir, provocar cambios en la estructura cognitiva del aprendiz. Ello es posible por medio de preguntas generadoras que se convierten en oportunidades interesantes para estimular, a través del diálogo y la interacción, (el aprendizaje colaborativo) nuevas lecturas del mapa y así estimular el ejercicio de los procesos de diferenciación progresiva y de reconciliación integradora, apareciendo entonces en el mapa, los diferentes niveles jerárquicos producto de las denominadas relaciones cruzadas.

Las metodologías para incentivar el aprendizaje de construcción de mapas conceptuales, están directamente relacionadas con la generación de nuevos aprendizajes. Por eso el mapa conceptual es considerado una herramienta muy poderosa para generar aprendizaje significativo.

Estas consideraciones teóricas se convierten en argumentos para rescatar el hecho, de que los mapas conceptuales no deben ser utilizados como herramienta de calificación (comprobación de cuánto sabe el aprendiz), sino que pretenden motivar a una comprensión más integral en la que la evaluación que genera está directamente relacionada con ***las habilidades para relacionar*** que posee el aprendiz.

Si bien se podría definir una lista de criterios que oriente en la evaluación de diversos mapas, y que permita señalar que hay diferencia en la calidad de las relaciones, (basándose en el tipo y calidad de los enlaces, en la cantidad de niveles jerárquicos, en la cantidad de conceptos relevantes, en la pertinencia y legitimidad de las proposiciones presentadas), que sin duda invita a la calificación de los mapas, es importante continuar trabajando en el diseño de estrategias para estimular el diseño de buenos mapas. Se espera haber contribuido con ello.

5 Bibliografía

Ausubel, D.P, Novak, J. D (1978) *Educational Psychology: a cognitive view*. New York.

Beirute, L. (2004). *Los mapas conceptuales herramienta poderosa en la resolución alternativa de conflictos*. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra.

Beirute, L. (2002) *La construcción del sentido de lugar*. Capítulo Introductorio del libro: Deslizamientos en Costa Rica, Escuela de Geología, Universidad de Costa Rica, en proceso de publicación.

Beirute, L. (1995). *La génesis del número en el niño, resumen de la teoría de J.Piaget*. Publicación que forma parte de la antología de estudio de cursos sobre Psicología Educativa en la Escuela de Psicología de la Universidad de Costa Rica.

Beirute, L. (2006). *La construcción de mapas conceptuales en la etapa preescolar*. En A. J. Cañas, J. D. Novak (Eds.), *Concept Maps: Theory, Methodology, Technology*. Proceedings of the Second International Conference on Concept Mapping, San José, Costa Rica: Universidad de Costa Rica.

Maldonado Gonzalo, (1996) *Teorías de Piaget*. Artículo en Internet: www.monografías.com.teorías-piaget

Novak, J. D., & Cañas, A. J. (2006). *The Theory Underlying Concept Maps and How to Construct Them* (Technical Report No. IHMC CmapTools 2006-01). Pensacola, FL: Florida Institute for Human and Machine Cognition. Dispoible en: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm.

Piaget, J. (1969). *Seis estudios de Psicología*..Barcelona.Ed.Six Barral.

Piaget, J. (1981). *Psicología y Epistemología*. Ed. Ariel.

Rodríguez, M. (2004). El conocimiento lógico-matemático, Disponible en: www.investigacion.ve.tripod.com/cap12.

Documento : Fundamentos teóricos de la educación preescolar. Ministerio de Educación, República de Venezuela.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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RUTA DE ESTUDIOS MUSICALES. LA UTILIZACIÓN DE MAPAS CONCEPTUALES EN PROCESOS DE APRENDIZAJE

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Abstract. La ruta de estudios musicales atiende a los estudiantes de los primeros semestres de diversos programas profesionales. Una primera aproximación de esta ruta ofrece a los estudiantes contextos donde la relación a los *objetos musicales* se efectúa desde elementos familiares a sus experiencias, brindando un reconocimiento de las características del sonido de manera básica, aunque, no sea aún lo suficientemente significativo. No obstante, en la búsqueda de una mejor representatividad se plantean procesos donde se elaboran diversas relaciones desde los contextos creativos, sociales e históricos. Esta actividad se desarrolla con el apoyo de los mapas conceptuales hasta logra escalar la construcción de conocimiento, trabajado de manera colaborativa y ampliando de esta forma la experiencia de aprendizaje.

1 Introducción

La ruta de estudios musicales atiende a los estudiantes de los primeros semestres de diversos programas profesionales, lo que demanda a los docentes pensar cómo crear nuevos vínculos entre la música y las distintas áreas de conocimiento, de manera que estos estudiantes sean capaces de reconocer la música en un contexto sociocultural específico.

El objetivo principal se centra en la formulación de estrategias pedagógicas para permitir la construcción de nuevos modos de pensar el devenir histórico del hombre visto a la luz del fenómeno de la música y asegurar la práctica de perspectivas de pensamiento en los aprendices no doctos en el lenguaje musical.

Algunos de los procesos se desarrollan con el apoyo de las tecnologías de información y comunicación (TIC) para potenciar la interacción de los aprendices con otras realidades, que de otro modo se ven atenuados en los espacios académicos tradicionales. Es así, que en este tipo de escenarios el uso de herramientas como los mapas conceptuales se establece como un excelente mediador para dar salida a unas estrategias didácticas coherentes a los requerimientos del diseño del programa curricular. Estas estrategias, con el apoyo de tecnología móvil dinamizan, además, modos de comunicación y colaboración entre los estudiantes y de estos con sus docentes. Esto permite escalar la construcción significativa de conocimiento de una manera colectiva, ampliando de esta forma la experiencia de aprendizaje.

2 Antecedentes

Los educadores e investigadores se han interesado durante estas últimas décadas en las opciones de representación de los conocimientos que proveen los mapas conceptuales, tanto para procesos de enseñanza-aprendizaje (Edmondson, 1995; Ferry et al., 1998; Horton et al., 1993; Chmeilewski and Dansereau, 1998; McCagg, 1991, Arbea et al., 2004; Baer et al., 2004; Beresiartua et al., 2004; Esteban-Duarte et al., 2004; Henao et al., 2004), como para procesos de evaluación (Aidman and Egan, 1998; Rice et al., 1998, Acuña et al., 2004; Izquierdo et al., 2004; Palazio et al.; 2004) entre muchos otros autores. No obstante, estas representaciones al intentar contextualizar la complejidad de los dominios de conocimiento requieren enriquecer, con objetos multimediales, los textos y las estructuras jerárquicas de los mapas, facilitando de esa forma la visualización, manipulación, comprensión y apropiación de los conceptos (Shephard, 1967; Jonson-Laird, 1983; Dowling & Harwood, 1986).

Antes del año 2005 en la ruta de estudios musicales de la Universidad EAFIT (Medellín-Colombia) al abordar los objetos de formación pertinentes, se obtenía una teorización de las formas que no expresaban mucho al estudiante que aún carecía de experiencia sonora para relacionarse de manera coherente con esa teoría. Es así que se busca una estrategia diferente que logre adecuarse a las necesidades de apropiación y construcción de conceptos musicales por parte de la población estudiantil no alfabeta respecto a las formas y lenguaje de la música.

2.1 Objetivos

Diseñar una estrategia didáctica con la mediación de TIC que permita integrar conceptos musicales a estudiantes, que no han tenido formación musical previa, a partir de la interpretación de los procesos creativos en diferentes momentos históricos.

3 Metodología y análisis

Metodológicamente se integran los procesos de trabajo de los estudiantes en varias fases:

La primera fase, propone una didáctica para que los estudiantes relacionen los *objetos musicales* desde elementos familiares a sus experiencias. En ese sentido, se generan acercamientos a los fenómenos acústicos de manera experimental, confrontando las diferencias entre "timbre", "altura", "registro", "secuencia", "intensidad" y "brillo". Luego, con estos elementos se aborda un primer acercamiento a las percepciones auditivas identificando los elementos de "ritmo", "melodía", "armonía" y "forma", relacionando de manera explícita la representación de sus códigos con el fenómeno físico equivalente. En esta aproximación a los elementos del sonido, se tiene como finalidad acercar de manera básica el reconocimiento del lenguaje de la música desde una experiencia auditiva, sin que por supuesto, se logre aún caracterizar de manera significativa los conceptos del mismo.

La segunda fase, retoma estos códigos desde la contextualización de relatos históricos con los cuales los estudiantes recopilan información, efectuando procesos de clasificación, diferenciación y contraste. Aquí, con el apoyo de CmapTools (Cañas et al. 2004), se identifican los conceptos de "estilo", "variación" y "transformación" de las formas musicales relacionados con los "contextos culturales" específicos. De esta manera se logra iniciar el escalamiento de una apropiación del lenguaje para expresar el objeto musical y sus diferentes lecturas en contexto.

La tercera fase, permite desarrollar procesos que retoman las inducciones elaboradas en la fase dos. A partir de acciones de abducción y deducción se constituyen "mapas conceptuales" que afinan los conceptos ya elaborados. En este proceso, se concretan escenarios o relaciones respecto a: (1) procesos estéticos en contextos sociales y (2) elementos que propician la transformación cultural en el dominio de los objetos musicales.

La construcción colectiva a través de CmapTools proporciona la integración de los conceptos musicales a partir de la "interpretación" de procesos de creación musical en diferentes momentos históricos. Este acercamiento se desarrolla partiendo de lo general a lo particular o de lo particular a lo general, hasta afinar y lograr de una manera negociada, situaciones de análisis y síntesis conceptuales de carácter significativo para los aprendices y las intenciones de formación de la ruta.

Se describen a continuación las acciones desarrolladas por los estudiantes en la construcción y elaboración de los conceptos usando CmapTools:

a) Dar cuenta de los temas que los estudiantes de manera grupal deben abordar en cada nivel. Respecto a ello se comienza con un proceso de búsqueda de información que cada equipo (de estudiantes) selecciona de acuerdo a los intereses y orientación de su investigación. En esta acción se implementan los siguientes pasos: (1) Los estudiantes se informan sobre las características de rigurosidad y el estándar obligatorio para referirse a los textos bibliográficos y/o contenidos presentes en la red. (2) Una vez que se hace la especificación de carácter técnico, se aborda el proceso de exploración con el apoyo de buscadores y metabuscadores, secciones especializadas de datos y acceso a lugares académicos expertos. Esta actividad se desarrolla orientada siempre a los estudiantes sobre la importancia de definir criterios y sentido alrededor de la búsqueda e indagación de la información.

   Cada participante asume de manera autónoma su lugar y papel en el proceso de búsqueda, clasificación y reconocimiento de la información y su relevancia para concretar interrelaciones de tipo conceptual. Esta situación obliga a los integrantes de cada grupo a estructurar bloques de nuevos enlaces, relaciones, conceptos, interrogantes y nuevas premisas de indagación en su propio discurso analítico de la información primaria.

En un ejemplo sobre "El canto profano en la edad media", el equipo presenta su inquietud sobre el tema de los trovadores a partir de ubicar la información en búsquedas avanzadas y en servicios especializados ofrecidos por el sistemas de bibliotecas de la Universidad. A partir de esta compilación de información primaria se ubican los temas en orden jerárquico. Esta primera estrategia didáctica hace referencia a procesos de inducción como dinámica para ocuparse de la recopilación de información. La información recopilada precisa encontrar su lugar en el contexto estudiado y su relación con el momento histórico desde los lineamientos prefijados por cada grupo. Las actividades se abordan alrededor de los temas específicos por cada colectivo, a partir del primer acercamiento temático con el apoyo de los mapas conceptuales (ver figura 1). La representación conceptual de cada tema, al igual que los conectores de relaciones y estructuras de jerarquías permite observar los niveles de comprensión, en cada grafo particular. Los procesos de construcción del mapa conceptual se realizan desde una primera jerarquización de los conceptos, asumida (generalmente) a partir de los títulos o los subtítulos seleccionados, para luego efectuar una revisión de las relaciones conceptuales presentes en los documentos desde las discusiones planteadas por cada equipo.

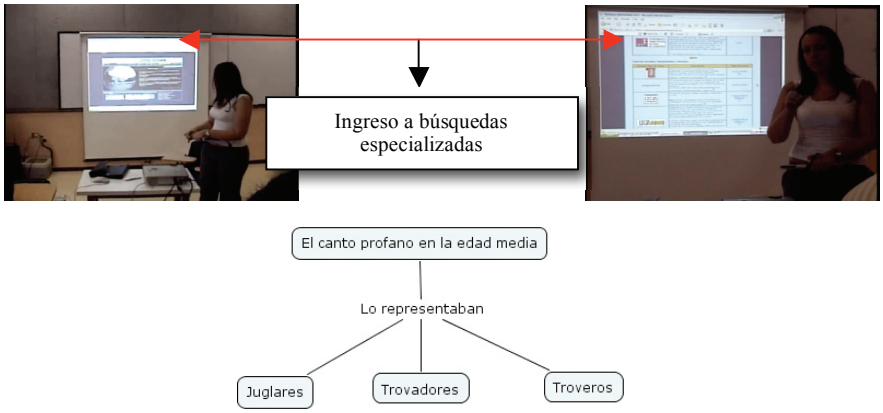


Figura 1

b) Plantear un primer proceso de análisis y síntesis: Este ejercicio exige la negociación de los conceptos y sus relaciones fundamentales para poder efectuar la construcción del mapa conceptual y de los contenidos específicos de la investigación en forma grupal. Cada subgrupo de estudiantes negocia al interior de su grupo la pertinencia de la información que selecciona para lograr la investigación. A partir de allí, se generan discusiones y negociaciones respecto a la validez de las relaciones entre los conceptos, la construcción de otros nuevos o de macroconceptos. Esta acción de síntesis se desarrolla con un acompañamiento docente, antes de que cada subgrupo confronte con los otros equipos sus puntos de vista sobre los conceptos, jerarquías, relaciones y sus diferentes temáticas (ver figura 2).

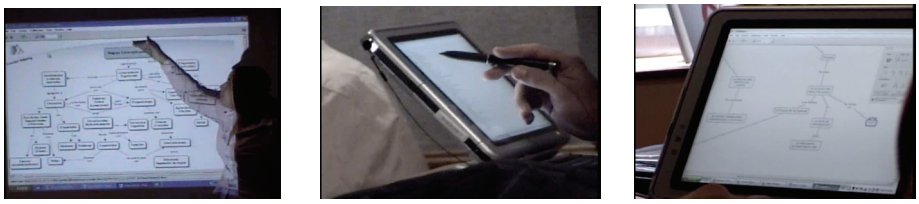


Figura 2

Lograr los procesos de síntesis colectiva es el resultado del ordenamiento planteado por los diferentes grupos de estudiantes respecto a la información clasificada y seleccionada por las líneas de interés en torno a los mapas conceptuales. La descripción de las conexiones entre los distintos contenidos y la forma como se comprenden los espacios de saber, se hacen manifiestos en los mapas como información gráfica, textual y/o sonora. Los resultados de las búsquedas se evalúan a partir de la comparación de los primeros textos abordados, con una segunda selección temática particular para cada equipo de estudiantes, relacionada

intencionalmente a partir de la pregunta trazada para responder a los objetivos iniciales de cada grupo. En este paso, los estudiantes juzgan la pertinencia de los diversos tipos de materiales, calificando la importancia que los diferentes archivos de carácter gráfico, sonoro y/o textual, tienen con respecto al eje central de su búsqueda. Las inferencias colectivas tienen un papel relevante en este aspecto, ya que cada estudiante debe defender la importancia de su selección y finalmente es el equipo quien consensúa la pertinencia de la ubicación. Como resultado, se observa el desarrollo de habilidades clasificación, diferenciación, contraste y argumentación para la elaboración de razonamientos lógicos y de sustentación teórica de los procesos de inclusión, o exclusión, de esos datos en la investigación. Los mapas comienzan a articularse cuando las discusiones asumen rumbos claros y definidos por consenso a partir de la apropiación de consciencia sobre el relato histórico y su relación con el objeto musical.

c) Cualificar los contenidos y su representación. Los estudiantes reconocen y utilizan las herramientas para adicionar información sonora, visual y textual como recurso para ampliar la comprensión de los conceptos, confrontando el sentido del material escogido con el proceso de síntesis planteado (ver figura 4). En esta parte del proceso, los estudiantes autorregulan la cantidad y la calidad de la información que puede adicionar a partir de la discusión que se genera con los otros grupos y al confrontar cada equipo sus mapas. Evitar la esquematización de los contenidos por parte de los estudiantes y la reducción de los aprendizajes a la simple memorización de la información, exige una diferenciación de los conceptos y conectores desde una comprensión retórica de los materiales indagados. El resultado de este proceso plantea una reacomodación de los conceptos seleccionados y sus jerarquías en los mapas conceptuales. Esta estrategia incorpora, además, la interpretación de los textos desde los intereses descritos en los conceptos y su relación con los objetivos temáticos. Los estudiantes trabajan siempre con datos conocidos dependiendo de las circunstancias y de la densidad o de la complejidad del tema o de las ideas contenidas en la información antes de su análisis. Para hacer comprensible *el saber indagado*, la sustentación de los temas y la articulación de las estrategias, obligan el uso de competencias comunicativas para generar diferenciación o relación temática.
(ver servidor de Cmaps:
/eafitcolombia/rutademusica/historia1grupocarlosmario/santiagofedericojorge/juglar;
/eafitcolombia/rutademusica/historia1grupocarlosmario/santiagofedericojorge/lostrovadores;
/eafitcolombia/rutademusica/historia1grupocarlosmario/santiagofedericojorge/trovadores2).

d) Ampliar las conexiones conceptuales. Los estudiantes concretan las nuevas conexiones que permite o demanda su mapa conceptual respecto a relacionarlo con los mapas de los otros grupos, lo que conlleva a construir diálogos específicos entre los elementos planteados, los conceptos musicales, la ubicación de los temas desde los conceptos y el sentido que cada discurso impone. Esto sucede, cada vez que se generan nuevas relaciones, la introducción de otras variables y nuevos contenidos. En el ejemplo "El canto profano en la edad media" los recursos adicionados permiten escuchar músicas relacionadas con los temas históricos a los cuales se hace alusión en el transcurso de la investigación, de la misma manera la información gráfica y los recursos de texto se comparten entre los diferentes grupos y los estudiantes cualifican la información según la pertinencia que tenga con el desarrollo del tema (ver figura 4).
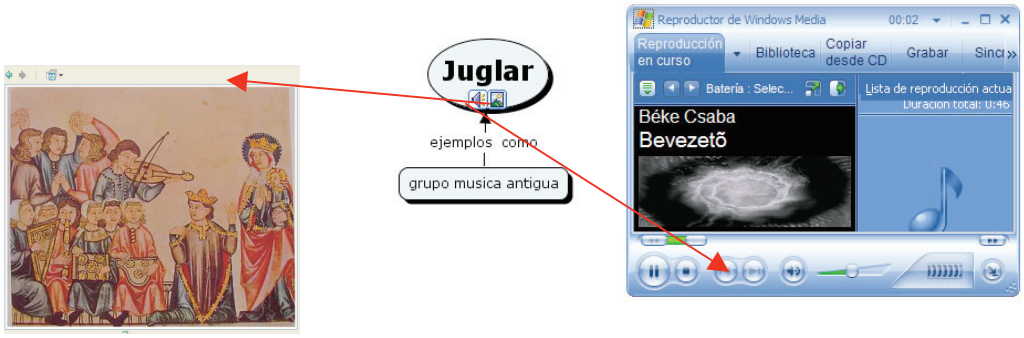


Figura 4

e) Elaborar conclusiones. Los estudiantes deben evaluar las relaciones que se presentan en la realización del mapa y elaboran un informe de resultados y aprendizajes. Este informe se expone y sustenta frente a todos los integrantes del curso, en él se explica cuales fueron los encuentros iniciales con los contenidos y cómo a partir de la transformación de los conceptos, relaciones y jerarquías se hacen explícitos elementos y condiciones que permiten cambiar la percepción que se tenía respecto a la experiencia de creación musical en ese periodo histórico (en "El canto profano en la edad media" para este caso), teniendo en cuenta las diferentes variables culturales a las que fueron sometidos los diferentes conceptos (ver figura 5).

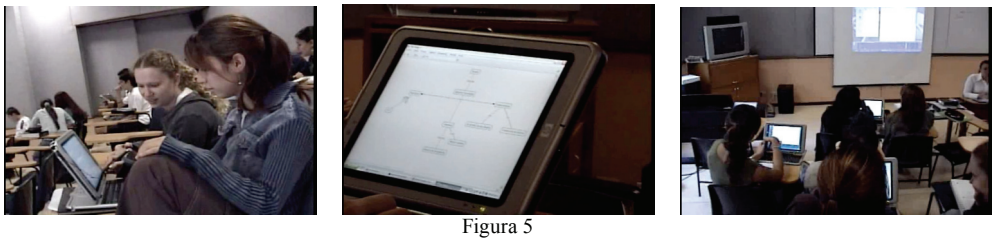


Figura 5

f) Publicación. Finalmente los estudiantes suben los mapas en la red y los dejan disponibles a los aportes y transformación que otros estudiantes puedan percibir de ellos, ampliando la discusión y/o contenidos que se presentan como memoria del trabajo realizado durante el proceso. También, aquí el docente confronta perspectivas que aportan a la transformación y cualificación del curso de la ruta para procesos posteriores de elaboración y diseño de los contenidos del mismo.

La concreción de mapas con elaboraciones más densas se desarrolla a partir de asumir acciones de complemento con la información presentada por los otros subgrupos. Este proceso se desarrolla, fundamentalmente, a partir de la construcción de inferencias y elaboración de adbudciones desde esos otros temas, articulando los nuevos conceptos y sus relaciones con los ya existentes, configurando "diálogos enriquecidos" de lo macro a lo microconceptual en los nuevos mapas conceptuales. Esta situación se puede observar en la siguiente referencia, en la que ya se incorporan elementos desarrollados por otros subgrupos: /eafitcolombia/rutademusica/historia1grupocarlosmario/juansebastianvilla/arquitecturagotica.

Algunos comentarios al final de la experiencia realizados por estudiantes:

- *Creo que es un muy buen incentivo para que la clase sea más interesante, además es menos aburrido que escuchar todo el tiempo hablar*.
- *He estudiado sistemas porque me gusta todo este rollo de las nuevas y viejas tecnologías, móviles y fijas, pero nunca en una materia nos habían hecho llegar tan lejos como en la ruta, el hecho de entregarnos un portátil a los estudiantes es ya revolucionar el modo de ver una materia ... El mapa conceptual lo publiqué en clase***.**
- *La actividad con los computadores me pareció muy interesante, sobre todo lo que nos enseñaron de los buscadores, especialmente el metabuscador y me pareció muy útil la base de datos de la biblioteca*.
- *Desde mi punto de vista las nuevas tecnologías que se están implementando en la universidad nos favorecen el aprendizaje y el desarrollo de nuevos medios tecnológicos que en unos años pueden estar dominando el mundo, lo cual nos facilitará la vida para esa época, …*
- *Trabajar con nuevas tecnologías en la universidad sobre todo en estas materias de la ruta, nos son muy importantes para la facilidad, agilidad y buen trabajo en clase. Además el actualizarse tecnológicamente, pues nuestro futuro va a ser regido por los computadores y mas, y que mejor que aprenderlos de una vez*.
- *Pienso que agiliza mucho las cosas, cada vez todo se puede hacer mucho más rápido, y es más accesible desde cualquier sitio, pienso que es una muy buena herramienta para el estudio, y también hace que este sea más flexible*.
- *Me parece muy buena herramienta para facilitar el aprendizaje de todos los estudiantes, de la universidad pues es fundamental que todos los estudiantes experimenten nuevas formas de conocimiento, …*

4 Conclusiones

Se observa que no todos los estudiantes logran diferenciar un mapa conceptual de la construcción de un texto lineal en los primeros procesos de análisis. Esta situación se supera de manera autónoma al interior de cada subgrupo en la medida que evoluciona el proceso. De la misma forma, se reconoce que los mapas presentan jerárquicas y relaciones más pobres al inicio del semestre y que se van enriqueciendo en información y complejidad en la medida que el semestre avanza.

La implementación de acciones colaborativas a través de los mapas conceptuales exige confrontar y correlacionar la información a ser integrada al mapa con aquella ya existente, la cual no siempre presenta opciones claras o fáciles para el aprendiz obligándolo a reflexionar sobre el concepto que quiere expresar y construir.

En el ejemplo "El canto profano en la edad media", una de las temáticas que mas motiva a los estudiantes es el tema de las cruzadas. En ellas se relacionan las gestas de caballería, la música profana de los juglares, los trovadores, los troveros desde el contexto de la fe y/o los procesos estéticos, entre otros, revalorando los métodos de comunicación y transmisión de la cultura. Los estudiantes tienen que leer textos de literatura y poesía medieval para ubicar los estilos musicales de maestros cantores y tradiciones colectivas de tradición oral, a su vez, efectuar búsquedas alrededor de la producción musical representativa de los grupos que en la actualidad ubican sus trabajos en la Web y que presentan parte de su realización musical en formatos de MP3.

Este proceso interdisciplinar se complementa por parte de los docentes ampliando la inserción de otros conceptos, por ejemplo, introduciendo la arquitectura o la pintura como variable para complejizar y subdividir los temas de los mapas conceptuales propuestos. A medida que la información de cada disciplina (música, arquitectura, vestido, comportamiento cultural, etc.) se incrementa, se hacen más complejas las conexiones entre los conceptos permitiendo una reflexión transdiciplinar entre la estética, el arte, los contextos culturales y el objeto de aprendizaje.

El desarrollo de síntesis y cohesión temática se logra cuando los estudiantes asumen de manera sistémica la reflexión recursiva alrededor de la elaboración de los mapas conceptuales, socializando las dificultades y manteniendo la fuerza comunicativa de los mapas respecto a la intensión temática de cada dominio de conocimiento, de manera discriminada y relacionada. Finalmente los estudiantes, antes de justificar los contenidos temáticos, presentan una sustentación de la forma como han elaborado los mapas conceptuales. A partir de estas dos últimas acciones se identifican las habilidades de los estudiantes en la realización de procesos de clasificación, diferenciación, contraste, análisis, argumentación, cohesión temática, síntesis, interpretación e inferencia que marcan sus recorridos y elaboraciones para configurar el encuentro con la música, la representación pictórica, arquitectónica y las diferentes manifestaciones culturales de cada región estudiada en su momento histórico.

El uso y dominio de herramientas como CmapsTools permite una gran movilidad en las estrategias para construir espacios de comunicación que dinamizan la relación estudiante-docente y estudiante-estudiante. Igualmente, permite fusionar en el diseño de los procesos de aprendizaje de una manera propositiva la relación e integración cualitativa de conceptos, con experiencias sonoras, visuales y textuales.

La utilización de información sin restricciones permite relacionar la historia de la música con conceptos generales planteados a través de los contenidos del curso. La apropiación del saber se integra al uso de las TIC, para permitir a los alumnos y profesores de la ruta experimentar con la integración de elementos de otras disciplinas con los de la música e iniciar aproximaciones diferenciadas a un entendimiento multicultural de la música desde los distintos momentos históricos.

En este sentido, una de las situaciones particulares se presenta al compartir los mapas existentes con los nuevos estudiantes (los del siguiente semestre), brindándoles de esta forma un contexto enriquecido para abordar la apreciación y apropiación de los conceptos musicales.

Algunas ventajas más relevantes que se observan al experimentar este recorrido son:

- La autogestión del conocimiento.
- Desarrollo de proyectos colaborativos.
- Eficacia en la apropiación del conocimiento.
- Ampliación del aula convencional a los espacios asincrónicos.

- Modernización en los procesos pedagógicos.
- Mejoramiento en los sistemas comunicativos.
- Capacitación y renovación de la actitud de los docentes y los alumnos respecto a la tecnología.

5 Reconocimientos:

A los docentes de la ruta de estudios musicales que dirige la profesora Diana Gutiérrez. A todos los estudiantes que con su motivación e interés participaron activamente en la construcción de un conocimiento socializado y pormenorizado sobre los temas relacionados con la historia de la música. A la Universidad EAFIT y Hewlett Packard quienes financiaron el proyecto "Aplicación de la tecnología móvil a procesos formativos en educación superior".

6 Referencias bibliográficas

Acuña, A. (2004) "Los mapas conceptuales y los procesos de asesoría y seguimiento en proyectos de innovación educativa" En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 13-16.

Aidman, E. & Egan, G. (1998) "Academic assessment through computerized Concept Mapping: validating a method of implicit map reconstruction." En *International Journal of Instructional Media*, 25(3), 277-294.

Arbea, J. (2004) "Mapas conceptuales y aprendizaje significativo de las ciencias naturales: Análisis de los mapas conceptuales realizados antes y después de la implementación de un modulo instruccional sobre energía" En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 45-48.

Baer, A.; Parchmann, I. & Demuth, R. (2004) "Concept Mapping as a Tool to Facilitate Goal-Oriented Communication and Cooperation Among Teachers" En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology.* Proceedings of the First Internacional Conference on Concept Mapping Navarra, España: Universidad Pública de Navarra Vol. 2, 57-60.

Bereziartua, J. (2004) "El sistema conceptual como técnica de facilitación del aprendizaje" En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology.* Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 75-78.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Chmeilewski, T., & Dansereau, D. (1998) "Enhancing the recall of text: Knowledge mapping training promotes implicit transfer." En *Journal of Educational Psychology*, 90(3), 407-413.

Dowling, W. & Harwood, D. (1986) *Music Cognition* Orlando – Florida: Academic Press.

Edmondson, K. M. (1995) "Concept Mapping for the development of medical curricula." En *Journal of Research in Science Teaching*, 32(7), 777-793.

Esteban, P.; Vasco, E. & Bedoya, J. (2004) "Los mapas conceptuales como herramienta de exploración del lenguaje en el modelo de van Hiele" En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 151-154.

Ferry, B., Hedberg, J., & Harper, B. (1998) "How do preservice teachers use Concept Maps to organize their curriculum content knowledge." En *Journal of Interactive Learning Research*, 9(1), 83-104.

Johnson-Laird, P. (1983) *Mental Models* Cambridge, UK. Cambridge University Press.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993).

Henao, M. & Arango, M. (2004) “Los mapas conceptuales como estrategia de conversión de conocimiento en la gestión de conocimiento” En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 215-218.

Izquierdo, M. (2004) “Los mapas conceptuales: Instrumento para el análisis de las narrativas Experimentales” En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 227-230.

McCagg, E. a. D., D. (1991) “A convergent paradigm for examining knowledge mapping as a learning strategy.” En *Journal of Educational Research*, 84(6), 317-324.

Palazio, G. (2004) “Aplicaciones de mapas conceptuales en PDAs para crear conocimiento y evaluar” En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 287-292.

Rice, D., Ryan, J., & Samson, S. (1998) “Using Concept Maps to assess student learning in the science classroom: Must different methods compete?” En *Journal of Research in Science Teaching*, 35(10), 1103-1127.

Shephard, R. (1967) “Recognition memory for words, sentences, and pictures. “ En *Journal of Verbal Learning and Verbal Behaviour* 6, 156-163.

Zea, C. & Atuesta, M. (2004) “Proyectos colaborativos y mapas conceptuales: Una propuesta válida para lograr aprendizajes significativos en ciencias” A. J. Cañas, J. D. Novak & F. M. González (Eds.), En *Concept Maps: Theory, Methology, Technology*. Proceedings of the First Internacional Conference on Concept Mapping, Navarra, España: Universidad Pública de Navarra Vol. 2, 381-384.

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SCORM STANDARD COMPLIANT LEARNING OBJECTS GENERATED FROM CONTENT ORGANIZED WITH CONCEPT MAPS

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Abstract. One of the greatest faced challenges in institutions that develop distance learning courses and training is the organization of contents and learning activities in a way that enables the improvement of the following aspects: reusability, portability, interoperability, modularity, durability, adaptability, and others that can benefit the institution that offers the course, as well as the people who will use it. One of the ways found by the education and training institutions to perfect these aspects is the use of Learning Objects in the production of such courses. The purpose of this paper is to present a methodology for the creation of Learning Objects, using contents that are organized and structured in Concept Maps in the authorship process of the courses. This methodology is based on the use of a software environment, the CMC-S, that using contents structured in Concept Maps will generate SCORM standard compliant Learning Objects.

1 Introduction

The content authorship process, in distance learning environment (DLE), demands a methodological severity to reach satisfactory levels of quality. The Instructional Project contributes for the achievement of this quality. According to (Wiley, 2000), the Theory of Instructional Project has always been helpful concerning the teaching-learning process. The significance of the Theory of Instructional Project became more evident with the increased use of distance learning environment. In presential teaching, the lack of an Instructional Project can be compensated with other pedagogical initiatives and even by a certain degree of improvisation by the teacher. In DLE this flexibility does not exist due to the inherent restrictions of this way of working. Therefore, the lack of an Instructional Project implies in several difficulties when it comes to elaborate a course.

Even if an Instructional Project is adopted for the production of a distance course, this does not mean that several desirable characteristics for distance learning environment courses are present. Nowadays, in the creation of a distance learning environment course, the following characteristics are believed to be important: reusability, interoperability, durability, adaptability. However, the presence of these characteristics is not assured by the simple adoption of a Instructional Project. The most widely accepted suggestion now, in order to confirm the existence of these characteristics in (DLE) courses, is the use of Learning Objects (LOs). A LO, using a definition created by the LTSC (Learning technology standards committee) by IEEE Institute of Electrical and Electronics Engineers, is “a digital or non -digital entity which can be used, reused or referred to during a teaching activity with technological support.” Examples of Learning Objects include multimedia content, instructional content, teaching objectives, instructional software and software in general, people, organizations or events mentioned during a teaching process that uses technological support ".

This definition, widely cited in literature about this subject, is of little practical use and, was probably elaborated not to limit the development of the e-learning market. Its generalization allows for any material to be considered a Learning Object. By this definition, if the material is used in any educational process with a technological base, it is considered a LO. According to (Hana & Silva, 2003) Learning Objects can be: any digital resource that can be reused to help the learning process, educational material designed and built in small sets in order to maximize the learning situations where they can be used and, they can be combined with other learning objects for building units of a course.

The Instructional use of Learning Objects is broadly discussed in (Wiley, 2000), (Gibbons, Nelson, & Richards, 2000) and (Hodgins, 2000). An already established Instructional Project can be used to generate Learning Objects, meaning that an educational organization or a company that adopts an Instructional Project can try to adjust it for the creation of LOs.

This project does not deal specifically with the Instructional Projects, but it demonstrates their importance and the connection of the Instructional Projects with the LOs. The SCORM Standard was adopted for the LOs design because, according to (Hana & Silva, 2003), the SCORM is a learning object model that offers a complete method

for the construction of courses following the concepts derived from Object Orientation. Since SCORM was one of the first international specifications and it is considerably used, it became a standard for the market and the academic community. This article presents a method, proposed for the production of Distance Learning courses. The contents are in the format of Learning Objects and, SCORM standard compliant. Concept Maps were also used for the organization of the contents. In order to make the proposed method able, a software prototype called CMC-S was created. It converts the course contents into Learning Objects using SCORM 1.4 standard.

This text is divided in five sections. Section 2 presents the work context and the theoretical hypothesis used to compose the proposed method. Section 3 presents the method in details. Section 4 presents the final considerations and future work possibilities. The bibliographic references of this article are described at the end.

2 Designing Instructional Projects using SCORM standard compliant Concept Maps

Concept Maps (CMs) are graphical representations similar to diagrams that indicate the connection between concepts using words. They represent a structure that may cover either very broad concepts or less inclusive ones. Concept maps offer a method to represent information visually. They are used to organize and determine the learning contents in such a sequence that it keeps the student optimally motivated. (Ausubel, Hanesian & Novak, 1980). In section 3 a Concept Map (CM) will be presented, along with some aspects for its appropriate elaboration.

The chosen tool to work with Concept Maps in this research is the CmapTools program (Cañas et al. 2004). From its 3x version on, CmapTools program presents a XML format of the exportation map, the XTM (XML Topic Maps). The XTM is a specification that provides a model and a grammar to represent the structure of the information resources used to define the concepts and the connections between the concepts. The XTM is defined by an independent consortium called TopicMaps.Org.[1].

The design and development of learning objects foresees the use of authorship languages and tools. Therefore, it involves a high amount of time and resources, especially when they involve multimedia and require human resources and financial investments. However, the following benefits can be achieved: Reusability: ability to incorporate educational components in multiple applications; Interoperability: ability to use components developed in a place, with a set of tools or platforms in other places with other tools and platforms; Accessibility: ability to access learning resources in a remote place and to use them in many other places; Durability: ability to keep using teaching resources when the technologic base changes, without using a re-project or a re-codification. The learning objects are more efficiently used when they are organized in a metadata (label) classification and stored in a repository (that can be integrated into a learning management system). The description of the object cataloguing attributes (metadata) must allow its research and recovery by different criteria. The metadata model for Learning Objects (LOM) is recommended by IEEE – LTSC.[2]. The attributes are grouped in 9 categories: *General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation, Classification.*

SCORM (Sharable Content Object Model) is a unified model of WEB based learning content suggested by ADL (Advance Distributed Learning) [3]. It defines a standardization for WEB based execution environments, aimed to facilitate the interchange between Learning Management Systems (LMS). SCORM integrates the specifications of several companies and organizations: IMS[4], AICC[5], IEEE (LSTC), ARIADNE[6]. SCORM is divided in four "books":

- Overview.
- Content Aggregation Model (CAM).
- Run-Time Environment (RTE).
- Sequencing and Navigation.

[1] http://www.topicmaps.org
[2] http://ltsc.ieee.org/index.html
[3] http://www.adlnet.org/index.cfm
[4] http://www.imsproject.org/
[5] http://www.aicc.org/
[6] http://www.ariadne.ac.uk/

CAM "book" was used for the development of this project. It allows the representation of a neutral learning taxonomy that helps designers and developers add learning resources that deliver a desired learning experience (CAM, 2005). We consider a learning resource any representation of information that may be used in a learning experience. One of the necessary activities in the process of creating and delivering learning experiences involves the creation, discovery, joining, or aggregation of simple Assets (simpler objects in SCORM) into more complex learning resources and organizing resources in a sequence of pre-defined deliveries. SCORM supports these processes and it is composed of the following items:

- Content Model: nomenclature that defines the content of a learning experience.
- Content Packaging: defines how to represent the planned behavior of a learning experience (content structure) and how to add learning resources activities in order to travel through different environments.
- Meta-data: a mechanism to describe specific states of the content model components.
- Sequencing and Navigation: base model used to define a set of rules that describe the planned succession and the sequencing of activities. "The activities may or may not refer learning resources to be delivered to the learner."

3 CM-LO Methodology

The prerequisite for using CM-LO Method, which assists the generation of SCORM standard compliant Learning Objects from contents organized in Concept Maps, consists in having an Instructional Project. This Instructional Project must be based on the use of Concept Maps for contents organization and construction; or it must be adapted from an existing Instructional Project so that it can work with Concept Maps. The Figure 1 shows the stages of the proposed method, which will be detailed later.

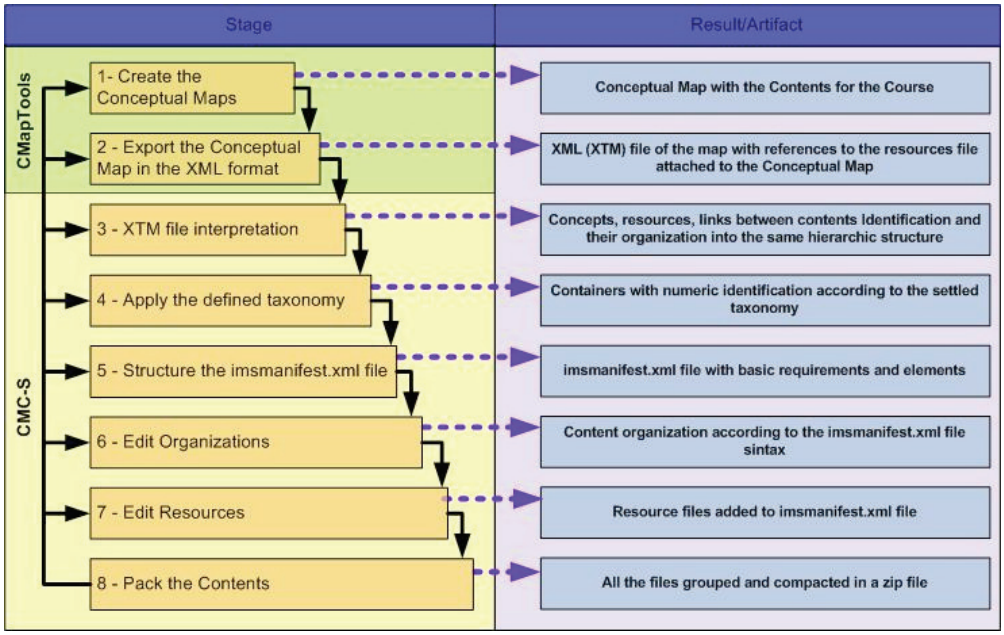


Figure 1. Stages of the proposed methodology.

1. The first stage of the methodology deals with the creation of the Concept Map of the course that will be converted into LOs format. Some observations will have to be followed for the elaboration of a concept map in the CmapTools when the objective is to elaborate content in the LOs format. The first one is to use directed arrows, which will indicate the navigation direction and the hierarchy levels, meaning that, when establishing a relation between concepts, the direction of the link must be clearly represented by the arrow. Another important detail is that for each concept created in the Concept Map, a file (resource) must be attached. This file must be associated to a type of media with contents which will be attributed to the concept. The last comment refers to the way that links between concepts must be done: when a concept is linked by more than one concept it will have to be linked directly to the concept and not to the sentence of an existing link in the concept. In Figure 2 we have an example of a Concept Map elaborated to explain the generation of Learning Objects about Project

Management. We can see in this CM that all the arrows have a direction and that all the concepts have associated resources (content media). When the intention in to elaborate a CM about any domain of knowledge, one of the great questions is what many authors call granularity, that is, how deep or generic must the concept be. These questions must be answered during the implantation of the Instructional Project, when the institution and the author team must get to a consensus.

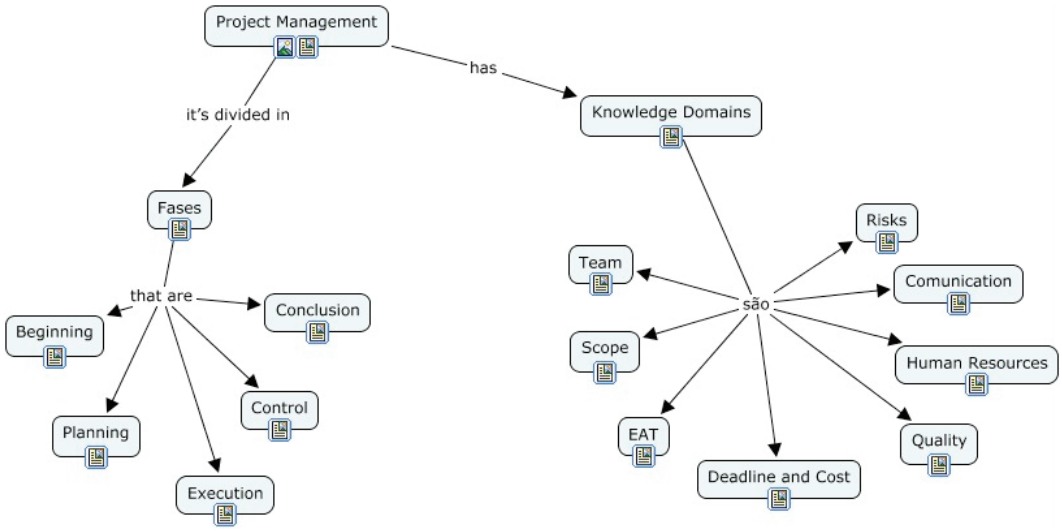


Figure 2. Concept Map about Project Management.

2. The second stage is exporting the Concept Map in a XML format. To export it the user must click on the CmapTools "File" menu, choose "To export Map As" and then click on "Archive XML". From the available formats he must choose XTM 1.0. XTM Format gives the concepts, the correct orientation and its proper links, providing a perfect representation of the hierarchic structure represented in the Concept Map. XTM Format also includes in its structure information about the content files attached to the CM.
3. Before describing this stage, it is convenient to point out that from this stage on, the third, to the last one, the eighth, the processes were all done by the tool developed for this project, the CMC-S. This third stage is about the interpretation and reorganization of the XTM file that was exported by the CmapTools. This interpretation identifies in the XTM file the concepts, the linking sentences, the propositions and the attached files that were inserted in the CM. Next, the reorganization task is done. It arranges, in a tree shaped hierarchic structure, the concepts and its relations according to the directing arrows placed in the CM to link the concepts.
   It is important to emphasize that to enable the generation of SCORM standard contents, from the CM, an adaptation is done. In the SCORM the contents are presented in Assets or SCOs, as it was previously mentioned in section 2. But Assets, well as SCOs can only have content attached to them if they are "leaf" objects, that is, if they do not have sub-items. In accordance with our proposal each concept on the CM will be transformed in a content unit (Asset or SCO) and it must have files attached, files where the media that refers to the concept will be. Since only the leaf units can have attachments, the CMC-S makes an adaptation so that all the Assets or SCOs can have attachments. How is this done?
   In order to adapt a CM to SCORM standard, each concept described in the CM will have to become an item of the organization. Also, the resources (media) attached to the concepts will have to be the Assets or the SCOs. To better explain what it is an organization in the SCORM standard we will analyze figure 3, where the relation between resources, assets, SCOs and organizations is demonstrated. If we transformed each defined concept on the MC into an Asset or SCO, the leaf concepts could only have resources (the media files) attached, but since one of the requirements for the proposed methodology to work appropriately is that each concept in the CM has its own Asset or SCO attached, then this could not be done. The solution was to transform each defined concept on the CM into an item of the organization.

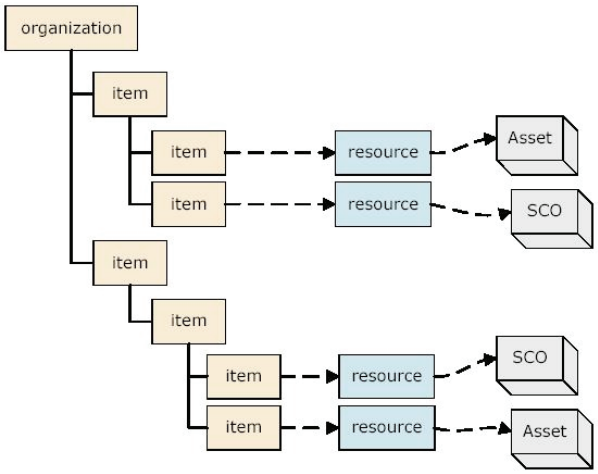


Figure 3. Content Organization [CAM, 2004]

4. In the fourth stage a taxonomy is applied to the hierarchic structure, to facilitate the identification of its levels. To apply the taxonomy, the hierarchic structure (tree) is run through and labels (chapter, section, numeration, etc.) are given according to the hierarchic levels. In this prototype, to label the hierarchic levels, a taxonomy was pre-established and that can be seen in figure 4.
5. In this fifth stage the CMC-S will generate imsmanifest.xml. According to CAM book, imsmanifest.xml is the main component of the content package of a SCORM standard compliant LO. It is a file in a XML format that describes the structure of the content and the resources associated to the package. A manifest in the root of the Content Package is necessary. The correct construction of a SCORM package depends directly on the correct construction of this file.
   The file imsmanifest.xml must be edited to be structured according to the XML Markup Language. It also must follow the definitions of the control files (* XSD and * DTD), where the data formats that must be contained in the XML elements are defined. The main components of the file are: <manifest>, <meta-data>, <organizations> and <resources> elements.
   Meta-data is information that facilitates the LOs identification, search and localization and they can be divided in nine categories (IEEE - LTSC): General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification. A Manifest can contain (sub) Manifest(s); in case of a course, for example, is grouped in sub-courses.
   The Items “Organizations and Resources” will be seen in stages 6 and 7.
6. At this stage the <organizations> element is edited for the construction of the SCORM package in imsmanifest. From this mark up LMS system finds the instructions of how to present the content to the learner. It is basically a map that shows the related activities. The activities represented in a Contents Organization may consist of other activities (sub-activities) that may also consist of other activities, and so on. There is no limit for the number of levels of sheltered items for the activities.
   Figure 4 presents a part that was expanded from the <organizations> element of imsmanifest generated by the CMC-S from the CM, presented in figure 2 and, the only organization of the map is emphasized, since it has only one top concept. And when there are more than one top concept other <organizations> element can be opened.
   Stage 3 describes what was done to represent in SCORM all the concepts of the CM that had resources, even if they were not "leaf" items. One adaptation had to be done at this stage, and it is demonstrated in figure 4: observe the <item identifier=”NO_0”> <title>1 - Project Management</title>, that in the concept map is represented by a concept that has an associated resource, and that in this representation of the SCORM does not have an associated resource. But there is a new sheltered item <item identifier=Leaf_1> that represents the resource <title> Subject_planning.htm</title> and the item <item identifier=Leaf_2> that represents the resource title>Global_Planning_Project.jpg</title>, meaning that, these are the two resources that were added in the CM to the resource Project Management. Then, we have the item <item identifier="NO_3"> <title>1.1 – Knowledge_Domains</title> that has a sheltered item that represents its sheltered resource, the item <item identifier="LEAF_4"> for the <title> Knowledge_Domains.pdf</title> resource, and so, the <organizations> hierarchic structure is constructed consecutively in such a way that each item has an associated resource, as if it was a leaf item.

In figure 4 the father concept in Area 1 can be seen, in Area 3 the items that correspond to the children concepts and, in Area 2 items that correspond to the resources associated to the concepts. Therefore the adaptation of the CM representation for the standard SCORM becomes evident, since it was possible to follow the requirement of this standard: that leaf items can only have associated resources and that items that have children cannot have associated resources.

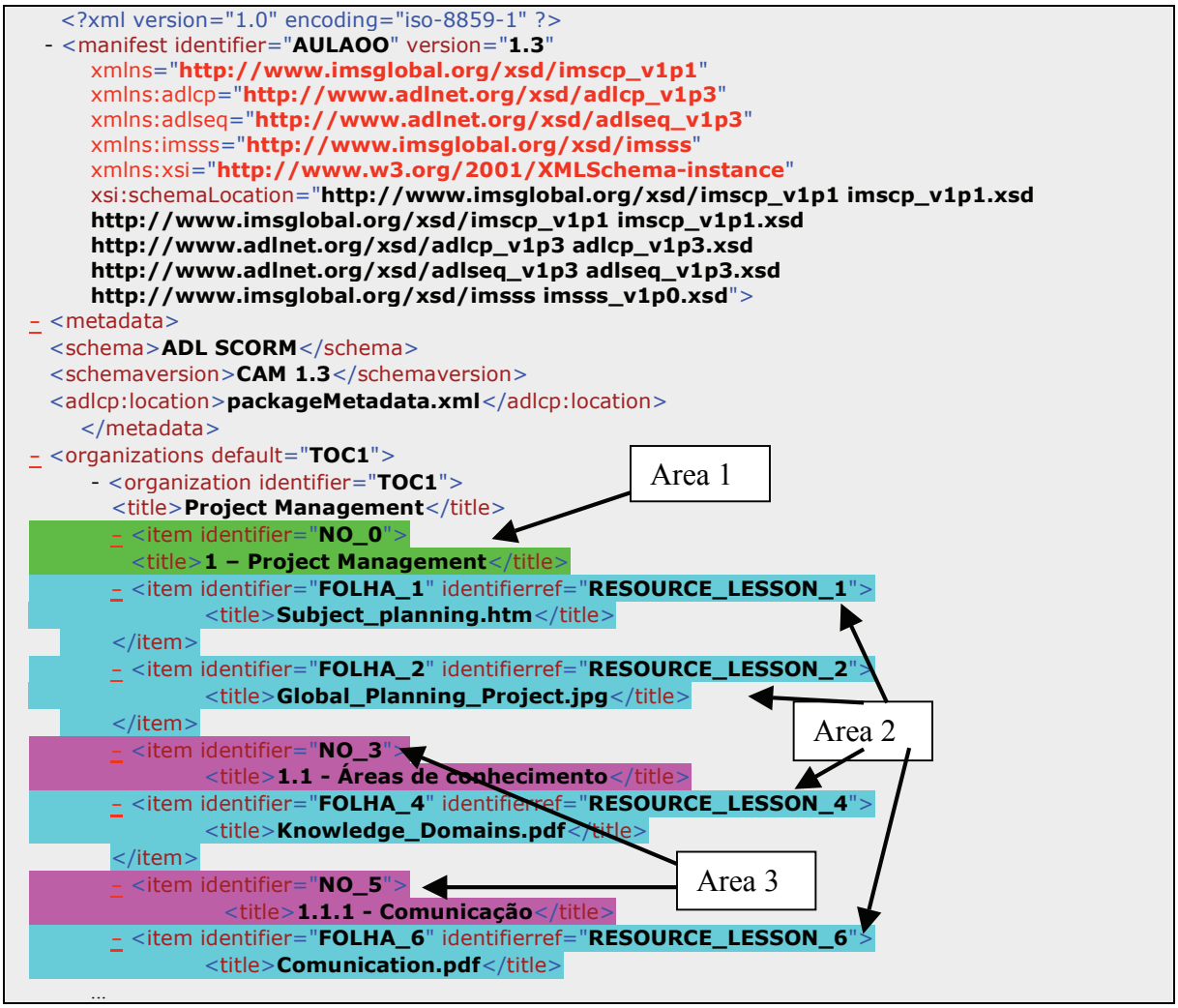


Figure 4. imsmanifest.xml

7. In the seventh stage the <resource> component of imsmanifest is edited, which is a reference collection for the resources that were used in the CM. All the resources used in the package will have to appear as a child element. Figure 5 shows how the <resources> element and its children elements are edited. These are imsmanifest elements, and they refer to the MC represented in Figure 2. The Figure 5 shows how the <resources> element was expanded, establishing that for each resource there must be a resource child element that will have the scormType definition that could be Asset or SCO. The difference between the two types is that SCO communicates with the LMS, meaning that, they could be activities or behaviors that are also launched as resources, while an Asset does not communicate with the LMS, which is the case represented in this work: <resource adlcp:scormType="asset". Href is the name of the file that will be used as resource, and it is followed by the identifier, which is the identification that the items of the organization use to get associated to the resources.

```
<metadata>
<schema>ADL SCORM</schema>
<schemaversion>CAM 1.3</schemaversion>
```

```
<adlcp:location>packageMetadata.xml</adlcp:location>
    </metadata>
<organizations default="TOC1">
- <resources>
  <resource  adlcp:scormType="asset"  href="subject_planning.htm"  identifier="RESOURCE_LESSON_1"
      type="webcontent">
<file href=" subject_planning.htm" />
    </resource>
            <resource              adlcp:scormType="asset"              href="Global_planning_project.jpg"
     identifier="RESOURCE_LESSON_2" type="webcontent">
<file href=" Global_planning_project.jpg" />
    </resource>
 <resource adlcp:scormType="asset" href="Knowledge_Domains.pdf" identifier="RESOURCE_LESSON_4"
      type="webcontent">
<file href=" Knowledge_Domains.pdf" />
    </resource>
   <resource   adlcp:scormType="asset"   href="Comunication.pdf"   identifier="RESOURCE_LESSON_6"
      type="webcontent">
<file href=" Comunication.pdf" />
    </resource>
     <resource      adlcp:scormType="asset"      href="Quality.pdf"      identifier="RESOURCE_LESSON_8"
      type="webcontent">
<file href="Quality.pdf" />
    </resource>
      <resource      adlcp:scormType="asset"      href="EAT.pdf"      identifier="RESOURCE_LESSON_10"
      type="webcontent">
<file href="EAT.pdf" />
```

Figure 5. Edit <resources>

8. The last stage of the methodology concerns the packaging of the resources that make the LO. After the creation and edition of the imsmanifest.xml file a compact file is created and it contains all the files that will compose the LO in the SCORM standard. The files contained in this package must be all mentioned in the manifest, without exception. The compact file is the way that the LO is carried to a LMS. The compact file must be zip format. To generate this package, in the CMC-S, after having already imported XTM file from the CmapTools, it is enough to click on the "To generate Package" button and choose the folder where the zip file will be recorded, together with all the necessary files

4 Final Considerations

The initial purpose of this project was reached, meaning that, it is possible to generate contents in the Learning Objects format from courses organized and structuralized through Concept Maps. Using the prototype CMC-S and the CmapTools it is possible to elaborate a Concept Map that will be constructed following some recommendations it can adjust to this method, and finally generate a course that is SCORM standard compliant and so that it can be imported by any LMS that supports this standard.

There is a restriction to this work, though. It concerns the Concept Maps authorship process, which must follow some suggestions for that the LOs can be generated. This opposes some authors who defend that the Concept Maps elaboration process must be as free as possible. But we do not see this restriction as an obstacle for the methodology, for the suggestions pointed in our method do not limit the action of the author in the Concept Map authorship. These suggestions exist only to discipline some actions of the author, as it was presented in stage 1 of the methodology.

It is important to mention that the ADL offers an environment for the validation of the packages generated in the SCORM standard (Test Suite 1.3.3 ST) and that the packages generated by the CMC-S are in perfect conformity with SCORM 2004.

The CM-LO methodology and the CMC-S prototype are currently in use at the Lutheran University of Brazil (ULBRA), where some professors are elaborating some courses and subjects using this method. One of the is subjects of the Information Systems course on Project Management that was created following this methodology already available on the site http://guaiba.ulbra.tche.br/moodle. Nowadays, four teachers are elaborating classes and courses through the methodology and using the prototype. Approximately 100 students are using this material elaborated by the teachers. We notice that in the education institution where the methodology is being tested, one of the main virtues pointed out by the professors who are testing it is that it is very user friendly, because all the

organization process of the course is done in the CmapTools, which is quite a friendly and intuitive tool. So, the professor creates the Concept Map of its course or subjects, adds the media (resources) and then exports its map in XML and converts it into the CMC-S, and he has a course that can be available in a LMS. The professors pointed another interesting aspect regarding the concepts reuse, in Assets form. The Assets are done in the Concept Map, meaning that when the author has to create a new course, he already has all the resources that the CmapTools offers to research and to save concepts that had already been used in other maps of the same, or different, knowledge domains.

One of the future works for this project is the creation of SCO type contents, because until now the prototype only works with Asset type contents, meaning that, the contents do not exchange information with the LMS.

References

Ausubel, D., Hanesian, H. & Novak, J. (1980). Psicologia Educacional. New York: Editora Interamericana.

CAM - Content Aggregation Model: Version 1.3.1, Online Version. Retrieved 20/03/06, http://www.adlnet.org.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Gibbons, A. S., Nelson, J. & Richards, R. (2000). The nature and origin of instructional objects. In D. A. Wiley (Ed.), The Instructional Use of Learning Objects: Online: http://reusability.org/read/chapters/gibbons.doc.

Hana, Jaime Kenji & SILVA, Jaime B. G. da (2003). 43 - Objetos de Aprendizagem (Learning Objects). BoletimEAD – Campinas: Unicamp / Centro de Computação / Equipe EAD.

Hodgins, H. W. (2000). The future of learning objects. In D. A. Wiley (Ed.), The Instructional Use of Learning Objects: Online Version.: http://reusability.org/read/chapters/hodgins.doc.

Spigarelli, B. (2004). Introduction to the SCORM for Instructional Designers. Online Version. Retrieved 10/03/06, from the WWW: ADLNet.org: http://www.adlnet.org/scorm/articles/3.cfm.

Wiley, D. A. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. A. Wiley (Ed.), The Instructional Use of Learning Objects: Online Version. Retrieved 27/01/06, from the World Wide Web: http://reusability.org/read/chapters/wiley.doc.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

STUDYING TRANSFORMATION: THE USE OF CMAPTOOLS IN SURVEYING THE INTEGRATION OF INTELLIGENCE AND OPERATIONS

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Abstract. The analysis of qualitative data in the social sciences is notorious for inviting criticisms of non-standardization and lack of "rigor." While many approaches to collecting qualitative data have been described, the follow-on stage of discovery and analysis is often underspecified, and can result in the appearance of haphazard or incomplete study.

This paper reports on the use of CmapTools for supporting the analysis of qualitative data. The real-world setting for the approach was a worldwide "survey" of United States Department of Defense Combatant Commands. The qualitative data analyzed was collected during interviews conducted by a team of researchers using forms of Cognitive Task Analysis (CTA) methods. The data was analyzed by another group of researchers. CmapTools was selected to enable inspection of the data because the application provided automated support for merging, organizing, and producing a variety of representations for analysis. Analytic and operational advantages of the approach, as well as dangers, are presented here.

1 Introduction

Within the social sciences, debate has long raged about the proper methods for understanding social phenomena. In the related domains of cognitive psychology, human factors, and organizational research, the debate focuses on two general schools of thought and practice. In one school, laboratory-based, tightly "controlled" methods are the tools of trade, and preferred for their production of statistically-manipulable data. In another school, "cognitive task analysis" (CTA) approaches to understanding naturally occurring phenomena are the methods of choice. The CTA approaches, while often more insightful than laboratory methods, produce qualitative data that is less structured and not uniformly manipulable. Naturalistic researchers, thus, often face criticism from laboratory-based researchers regarding the "rigor" of their approaches. Yet the critiques disregard their strongest appeal – bringing under inspection the natural world in all of its disparate occurrences and ostensibly "messy" forms.

To be sure, some of the critiques of CTA-based approaches are deserved, as they have historically provided detailed guidance in the collection of data yet underspecified their analysis methods. Researchers often feel themselves drowning in a sea of data and insight without the life-preserving benefits statistical analysis can bring. But it is not the absence of a standardized technique that causes the sea-sickness. Indeed, Blumer (1965) has pointed out that the process of inspection – not standardization of technique – is the *sine qua non* of scientific investigation of social phenomena:

> By "inspection" I mean an intensive focused examination of the empirical content of whatever analytical elements are used for purposes of analysis, and this same kind of examination of the empirical nature of the relations between such elements…such analytical elements may refer to processes, organization, relations, networks of relations, states of being, elements of personal organization, and happenings…The procedure of inspection is to subject such analytical elements to meticulous examination by *careful flexible scrutiny* of the empirical instances covered by the analytical element…The prototype of inspection is represented by our handling of a strange physical object; we may pick it up, look at it closely, turn it over as we view it, look at it from this or that angle, raise questions as to what it might be, go back and handle it again in the light of our questions, try it out, and test it in one way or another. This *close shifting scrutiny is the essence of inspection*.

What CTA-based researchers need are methods to support inspection.

This paper reports on the use of CmapTools (Cañas, 2004) for supporting the inspection of qualitative data. We worked with a team of researchers to inspect very large sets of CTA-based data, and in the process learned a number of lessons that are of value to researchers facing analysis of similar data. Thus, we believe the paper has a wider application than the CmapTools user community.

2 Application of CmapTools

In early 2006, the United States Joint Forces Command (USJFCOM) marshaled a team of researchers and experienced operators from across the intelligence community to conduct a survey of the nine Combatant Commands' (COCOM) efforts at transforming their intelligence operations, or their Joint Intelligence Operations Centers (JIOC). The number of interviews at each COCOM varied by available and appropriate personnel, time to collect, and other time-consuming activities. At the time of writing, over 175 interviews had been conducted at eight COCOMs and one subordinate command. The survey team was comprised of a group of 14 -18 collectors who traveled to each COCOM to conduct interviews with key personnel involved in intelligence operations (hereafter, the "forward team"), and a group of 12 analyzers, four of whom were the primary analysis team (hereafter, the "rear team"), who worked in Norfolk, Virginia. We comprise three of the four rear team.

The scope of the survey was broad. The intent of USJFCOM was to gather information regarding the COCOMs' current and future intelligence operations that indicated how they were arranged (i.e., Organizational Structure), what their missions were (i.e., Functions), how they accomplished these missions (i.e., Processes), and what sorts of information technology systems and related policies they employed (i.e., Systems and Policies). The USJFCOM was also interested in the relationships between COCOMs and other organizations. The overarching purpose of the survey was to identify best practices and their caveats, gaps and redundancies, overlaps between COCOMs, and comparisons between the COCOMs and concepts thought to be transformational. These findings, in turn, served as the basis for candidates for experimentation in future USJFCOM transformation efforts. The entire scope of the survey was captured in a concept map form, using CmapTools, shown in Figure 1.

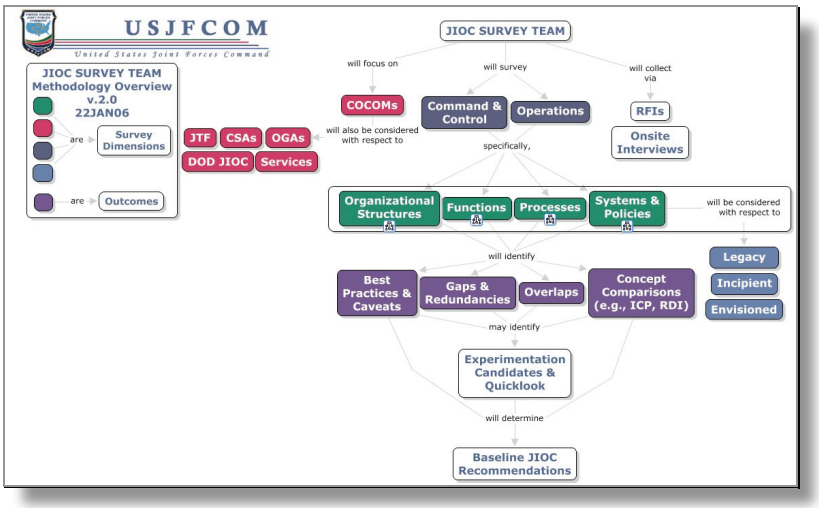


Figure 1. USJFCOM JIOC Survey Team Methodology Overview

The forward team received training in cognitive task analysis methods for conducting the interviews. The primary methods were Wagon Wheels and the Critical Decision Method. (Crandal, 2006). The Wagon Wheel is useful for dissecting information flow and identifying roles and functions, information requirements, types of information passed between team members, sources of information, decision and course of action impacts, criticality of information, and the impact of poor information flow. It can be used with highly experienced and novice subjects, in distributed and co-located teams, and in both one-on-one and group data collection sessions. As Moon (2004) suggested, it also lends itself to analysis in Cmap format. The CDM is highly useful for capturing deep, detailed data around processes of cognitive work (Crandal, 2006). Together, the CTA methods provided the interviewers with means to organize the interview sessions, flexible formats to collect in, and means to capture data in a variety of collection settings – i.e., collectors were not tied to standardized survey instruments.

The forward team organized into teams of two during interviews. One interviewer led the interviews by asking questions with regard to the areas of interest and CTA methods. The second interviewer captured the interview by hand in text format, and participated in the interview by asking questions. Following the interview, the second

interviewer captured the findings in an electronic text document that covered the entire scope of the interview.[1] Formats for the text documents were provided to the team; however, in practice, the team members also developed their own formats. Figure 2 shows the basic roles in each interview.

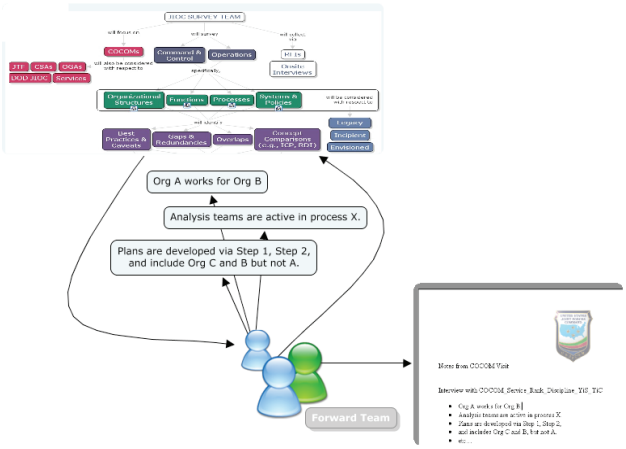


Figure 2. Basic roles of the forward team

As the survey progressed, the forward team provided their text-based data to the rear team. Upon receipt, the rear team manually converted the text documents into concept maps, shown in Figure 3. This required the rear team to interpret the forward team results, and document them in a "propositionally coherent" (Hoffman, 2006) format – that is, by creating node-link-node triples that in turn form stand-alone propositions. In most cases, and because the CTA techniques lent themselves to concept map representation and because concept maps are an effective form of knowledge representation, the translation was straightforward; yet some data points required reformulation of the forward team's data. The reformulation also enabled the rear team to disregard a small portion of data that was deemed not useful for analysis. Generally, a single rear team member concept mapped an interview from the forward team; however, in some cases, multiple rear team members worked against the same set of data, or revised the first rear team member's concept maps.

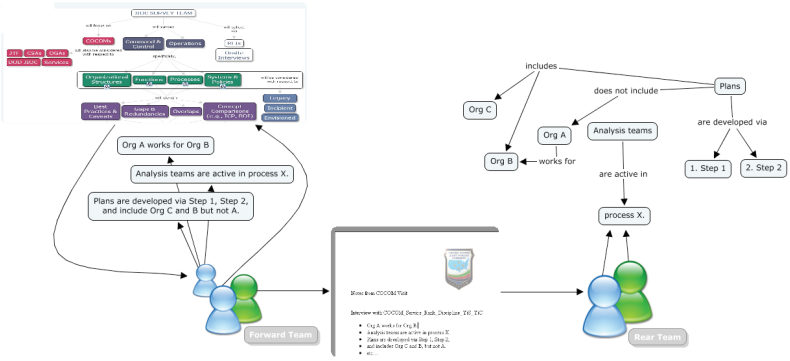


Figure 3. Data conversion to concept maps

Ultimately, the survey team was interested in knowledge models by which the interviewees reasoned and which guided their practice (Hoffman, 2006), as well as a "collective" model of each COCOM. Each interviewee at the COCOMs varied in their knowledge regarding the COCOM's current and future intelligence operations, and thus had different views on the same aspects of the operations. Any given interview resulted in the capture of any given

[1] Due to the classified nature of some of the data, the forward team was required to enter their data into a portal on a classified network. The portal corresponded to the areas of interest – e.g., Organizational Structure, Functions, Processes, and Systems and Policies. Forward team members were given the option of entering data directly into the portal, which could then be exported, or posting text documents to the portal. In either case, all survey data was collected into this central repository.

aspect of the COCOM's intelligence operations. Thus, multiple interviews may have provided convergence on particular aspects, while some interviews provided the sole collection against other aspects. The intent of the survey team was to provide a COCOM-wide perspective on each COCOM, which could then be used for comparison and to give a Department of Defense-wide view of intelligence operations. Thus, as the forward team progressed, the rear team continued to generate concept maps of their interviews, and the multiple maps were subsequently merged into "master maps," as shown in Figure 4. Rear team members varied in their preferences for the workable sizes of their maps – e.g., some preferred to map *all* of a forward team members' data from a given COCOM, while others elected to create maps on *each* interview. All, however, aimed to create propositionally coherent maps.

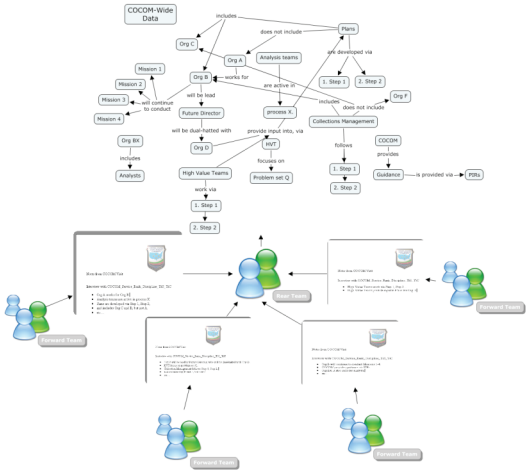


Figure 4. Merging multiple maps

The master map of one COCOM is shown in Figure 5, with the content of the concepts hidden from view due to its classified nature. The largest map, it contains 727 propositions, 495 concepts, and 580 linking phrases. It demonstrates the use of the rear team's color coding scheme to represent the temporal nature of findings. Interviewees provided data for each aspect with respect to legacy, incipient (i.e., newly formed or emerging), and envisioned aspects of operations. Findings (i.e., concepts) were color-coded by this temporal dimension.

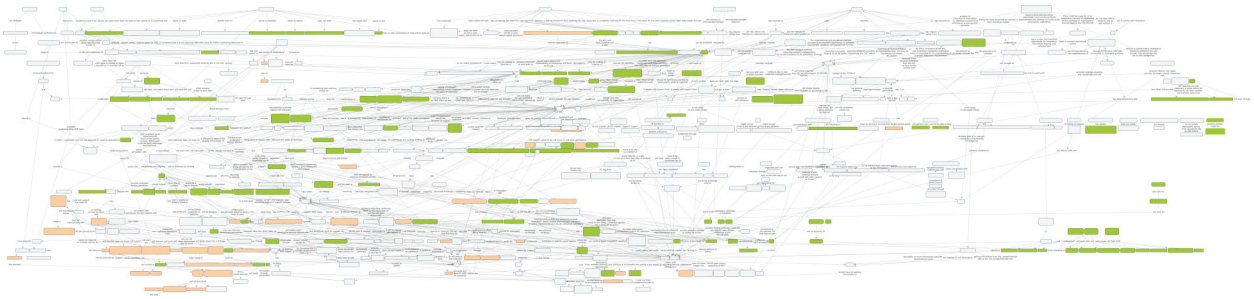


Figure 5. COCOM master map

Once all data from a COCOM was mapped, we used the CmapTools "Merge" capability to support automated merging of matching concepts. Other merges were made manually, as forward team collectors made varying references to like phenomena by the use of acronyms and other shorthand descriptors. For example, the "intelligence planning team" was referred to as "intelligence planning team", "intel planning team", "IPT", "IPTs", etc., none of which could be automatically merged. In this fashion, all related concepts could be grouped, either explicitly in by use of Nested Nodes, or not explicitly by spatial organization. Links, however, were never merged, as each was required to remain independent to ensure the propositional coherence. All links and non-merged concepts were spatially grouped to bring the entire map into a workable size, as shown in Figure 6, which is the re-organized version of Figure 5.

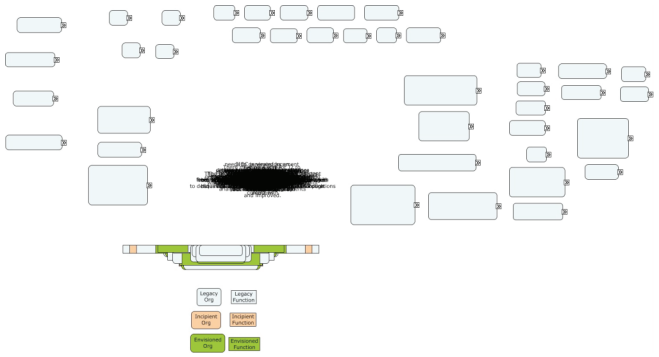


Figure 6. Reorganized COCOM master map

The value in the CmapTools-based organization of the data lied in the use of the Cmap List View, which provided a means to view all Concepts, Links, and Propositions in an Outline or alphabetically sorted lists. The View, shown in Figure 7, enabled the extraction of subsets of the COCOM datasets. In this format, a single rear team analyst had ready access to and quick and flexible manipulation of an entire COCOM dataset. The subsets lent themselves to closer inspection *within the context of the entire dataset*, descriptive modeling, comparison within and between COCOMs, and conversion of the dataset into a text document via copying. The subsets were selected and formatted using the Autoformat feature. Typically, we organized the data in the Horizontal Hierarchy. For larger subsets, we manually organized the data, spatially placing closely related links and concepts for review in context. Submaps were saved into new maps, which were then linked to analytic products, providing other organizational structures.

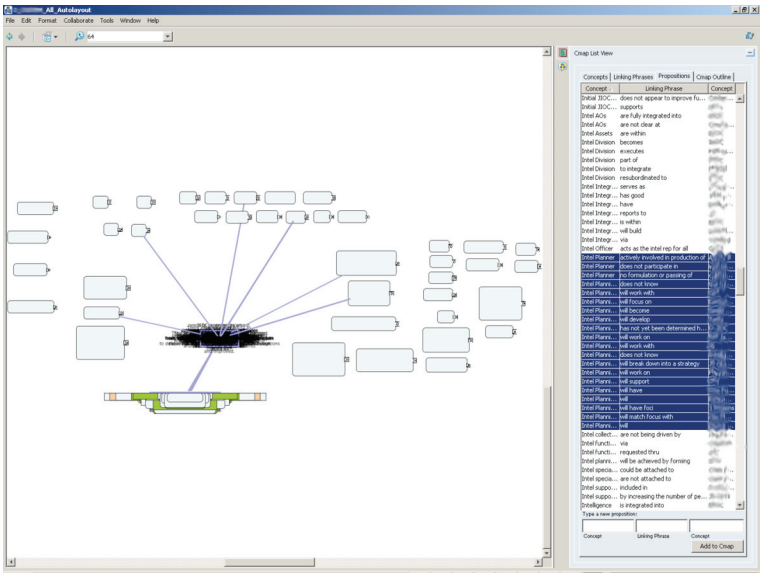


Figure 7. Reorganized COCOM master map in Cmap List View

3 Analytic and Operational Benefits and Challenges

The primary analytic benefits of the use of CmapTools in conduct of the survey lied in the merging of multiple datasets into a master copy, and the subsequent capability to select subsets of data for manipulation. We were able to consider organizations, functions, and processes in the context of *all the data collected about them*. Thus, what discoveries were made in one interview could be considered in light of other interviews. Representing the survey

data in concept maps for manipulation in CmapTools enabled the sort of careful flexible inspection that Blumer calls for – we could examine our data at different levels of subsumption, group our data, freely "move" our data to examine its relations to other data, and select subsets of data for closer inspection.

Yet, as Berkowitz (1997) has rightly noted, while computer-based qualitative analysis packages can be "helpful in marking, coding, and moving data segments more quickly and efficiently than can be done manually, the software cannot determine meaningful categories for coding and analysis or define salient themes or factors. In qualitative analysis…concepts must take precedence over mechanics: the analytic underpinnings of the procedures must still be supplied by the analyst." This sentiment agrees with Klein's Data/Frame model of Sensemaking (Klein, 2004). The act of sensemaking – i.e., the process of fitting data into a frame and fitting a frame around the data – does not proceed upward from data. Rather, frames – or explanatory structures that define entities by describing their relationship to other entities – help account for the data and guiding the search for more data. Frames reflect a person's compiled experiences. In order to make sense of the data, the rear team required some guidance from the forward team in the form of frames, or tentative hypotheses, about what the merged data ultimately reflected. Given the shear size of the master maps and even with the automated aids – e.g., Cmap List View and Autoformat – the rear team found it difficult to "gist out" the meaning of the data. This was particularly difficult for the rear team member who was less familiar with intelligence operations. As Hoffman (personal communication) has noted, even the most well constructed concept maps take time to digest and understand. To make sense of megamaps, the forward-team-provided-frames ultimately guided the search for sense, and the *rigor* involved should not be underestimated.

Another analytic benefit lied in the capability to represent many types of meaning in diagram form. We represented bilateral and multilateral relationships, processes, horizontal and vertical organizational structures, simple propositions, and temporal aspects. Our goal was to represent the knowledge captured in the interviews. Each of these types was, for the most part, understandable and clearly visible in the concept maps we created of individual interviews. However, in cases where multiple links were used to convey a complex relationship or steps in a process within a stand-alone map, those secondary links and processes could be lost when merged with other concepts and maps unless steps were taken in creating the stand-alone maps to specifically mitigate those effects (e.g. numbering steps or "freezing" links within nested nodes).

We cannot underestimate the advantages of the accessibility of our data in the Cmap List View. The capability to bring our data into a manageable size – i.e., as shown in Figures 6 and 7 vice Figure 5 – enabled us to overcome the formidable challenges inherent in digesting such a large and heterogeneous dataset in textual format – e.g., keeping names and acronyms straight, resolving contradictions, recognizing patterns. Each proposition could be examined in the context of the master map, and, by and large, each represented stand-alone expressions. Data expressing meaning about the same concept could be readily grouped and considered. In this format, however, we sacrificed one of the key differentiating features of concept maps. Hoffman (2006) has proposed several features that differentiate concept maps from other diagrammatic representations that use text and graphic elements, to include explicit yet unrestricted links, hierarchy-like morphology, morpho-semantic interactions, and dynamic state and representation. We rarely represented our maps in a hierarchical shape. Most of our Autolayouts were Horizontal Hierarchies, with no particular relations being more important or subsumed under others. For larger submaps, we spatially grouped concepts and links to encourage meaning-making, and we captured some levels of subsumption through merging and nesting nodes. Yet we were not as concerned with creating the familiar morphology as we were in gleaning meaning of the bilateral and multilateral relationships. We viewed this departure from 'standard' concept mapping as unimportant.

Regarding operational advantages Berkowitz noted, "since it takes time and resources to become adept in utilizing a given software package and learning its peculiarities, researchers may want to consider whether the scope of their project, or their ongoing needs, truly warrant the investment." While one of us was considered an expert user at the outset of the analysis phase, the other members had no experience concept mapping or using CmapTools. The ease of use of CmapTools during the survey allowed more time for relatively inexperienced users to focus on processing data and developing maps rather than learning to use software. The understanding of CmapTools' basic functions does not necessarily lead to the creative use of its functions to represent complex relationships. Indeed, while the ease of use of the CmapTools allowed the rear team to continue without much ado, and while most of the interview data was coherent and generally understood to mean the same thing by all who read it, the representation of that meaning in concept map format differed depending on the talents of the user. Further complicating the matter

were the varying talents of the forward team for representing their discovered knowledge in text format. At times it was necessary for the analyst to reword statements for visual appeal or ease of understanding. The ability to relate information economically without misstating or omitting the information turned out to be problematic in certain circumstances. For instance, the team devised color codes to denote the chronologic categories of Legacy, Incipient, and Future. This temporal aspect was not always obvious in the context of the interviews and was left up to the interpretation of the rear team analyst. Accounting for that interpretation caused some friction. For our purposes, however, we believed the analytic benefits of merging all of the data outweighed the inter-mapper differences, and mitigated potential mistranslation of the interview data. We saw great power in the ability to create and display – both to the forward-team collectors and our eventual customers – the audit trail from our data to our conclusions.

4 Summary

Through the context of our efforts on a major data collection and analysis effort, we have presented an application of CmapTools for enabling the analytic process of inspection. CmapTools amplified the sensemaking process of inspecting by providing capabilities to capture, merge, organize, sub-select, and display very large datasets. Researchers using qualitative data may benefit from exploring and expanding our approach with other types of qualitative data.

5 Acknowledgements

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References

Berkowitz, S. (1997). Analyzing Qualitative Data. In Frechtling, J, Sharp, L. (Ed.), User-Friendly Handbook for Mixed Method Evaluations, Available online April 14, 2006 at http://www.ehr.nsf.gov/EHR/REC/pubs/NSF97-153/START.HTM#TOC

Blumer, H. (1965). Symbolic Interactionism. CA: University of California Press.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Crandal, B., Klein, G., & Hoffman, R., (2006). Working Minds: A Practitioners Guide to Cognitive Task Analysis. MA: MIT Press.

Hoffman, R. (2006). Eliciting and Representing Practitioner Knowledge. In Crandall et al., Working Minds: A Practitioners Guide to Cognitive Task Analysis. MA: MIT Press.

Klein, G., Phillips, J. K., Rall, E., & Peluso, D. A. (2004). A data/frame theory of sensemaking. In Hoffman, R., (Ed.), Expertise out of context: Proceedings of the 6th International Conference on Naturalistic Decision Making. Mahwah, NJ: Lawrence Erlbaum & Associates.

Moon. B. (2004). Concept Maps and Wagon Wheels: Merging Methods to Improve the Understanding of Team Dynamics. In Cañas, A. J., Novak, J., and González, F., (Eds.), Concept Maps: Theory, Methodology, Technology, Proceedings of the First International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

SYNCHRONOUS COLLABORATIVE PROBLEM-SOLVING VIA CMC: APPLICATION OF CONCEPT MAPPING

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Abstract. This paper presents a concise report of three experimental studies investigated application of concept mapping (CM) as a knowledge representative tool in synchronous collaborative problem-solving via CMC. The studies compared: synchronous collaborative CM in Face-to-Face (FtF) and via CMC, different types of CMC channels in collaborative CM, and different methods of synchronous collaborative CM via CMC (distributed, shared, and moderated).

1 Introduction

One of the most promising uses of CM is its integration into co-operative learning activities. In this situation the members of a group collaboratively construct their group maps. Collaborative CM can be used in different forms. For example collaborative sessions may be FtF or of a distance. They may be synchronous (all participants working simultaneously) or asynchronous (one collaborator draws his or her concept map and then passes it to other collaborator). Collaborative CM can facilitate the exchange of information and relationship between members of a group and clarify the collaborator's view on the topic. It can also support discussion about concepts among members of a group. There are not a lot of studies that consider collaborative CM, however most of them suggest that it could lead to effective discussions concerning concepts and thus enhance meaningful learning. For example, Baroody and Bartels (2000) showed collaborative CM promotes more questioning, discussion and debate among participants. Stoyanova and Kommers (2002) found synchronous collaborative CM provoked "a more intense collaboration" and resulted in "a more dense conceptual representation".

On the other hand, there are some negative views on the effect of collaborative CM. There are some studies that have found collaboration has little effect on participants' learning. For example Chung, O'Neil and Herl (1999) found the quality of concept maps was not related to teamwork process. In another study, they found construction of a collaborative concept map does not benefit from collaboration (Herl, O'Neil, Chung & Schachter, 1999). They compared a network collaborative CM with an individual CM. The results showed in individual CM students had significant improvement in mapping scores in comparison with the collaborative condition. This might be to do with the task. There is a good deal of evidence that creative tasks or ill-defined tasks are more effectively solved by individuals than by groups. A further significant development in the field of collaborative CM took place with the emergence of network technology and ICT. In this development, computers have been used to support collaborative CM since the mid-1990s. Now with some empirical studies on network technology to support collaborative CM, there have been some moves to create web-based CM with collaborative facilities. With the developments in using ICT for on-line learning environments, it seems more research is needed to investigate the methods and implications of using learning tools as an essential part of any educational environment. More specifically, some research has investigated learning by network supported CM and its related issues (e.g. Cañas et al. 2001).

Using CM in collaborative learning situations has been investigated by some researchers. For example, Chiu, Huang and Chang (2000) investigated the interaction patterns among participants to explore how participants use the communication process to accomplish a synchronous web-based CM task. They found that greater interaction with complex co-operation led to better performance in a group. They suggest any tool for communication or interaction in collaborative CM should be applicable and easy to use. Stoyanova and Kommers (2001) investigated the learning effectiveness of CM for computer-supported collaborative problem solving. They showed that a shared collaboration, when all members of a group collaboratively construct a map, is more effective than moderated or distributed collaboration. In moderated collaboration, a leader of a group constructs the map based on the members' opinions and in distributed collaboration members of a group distribute their maps together and every member construct his/her own map. De Simone, Schmid & McEwen (2001) showed university students preferred sharing concept maps and discussing with one another in a synchronous mode, where the immediate feedback helped in constructing maps. They used collaborative CM without web-based facilities. Komis, Avouris and Fidas (2002) used CM in the shared activity space of the environment as a knowledge representative tool and a text as communication

tool. They found participants managed to solve complex problem of data modeling similar to reference group that solved the problem using paper and pencil. They also found while the shared activity space played an important role in collaboration, the textual communication tool, despite its limitations, has been used effectively and is essential. Finally in one the more recent study on collaborative CM, Suthers, Hundhausen and Girardeau (2003) investigated the role of discourse and knowledge representations, here CM, in FtF and online collaborative learning. Although their main focus was on the discourse in online collaborative learning, they compare the learning outcome (an essay about the task) as well. The results supported a hypothesis that a knowledge representation like CM in the online situation could be more effective than FtF because participants must rely more on the representations to compensate for the absence of the richer attributes of FtF communication. However, the results regarding the output of the collaboration, essays, showed the inferential quality of the essays suffered in the online condition relative to FtF. They believed these results may show that online participants are not able to take full advantages of the representations as substitutes for conversation because they are not co-present. In summary, the idea of CM has been recognized for nearly two decades and several computer-based tools are now available. Some attempts are now being made to design web-based CM systems for synchronous collaborative CM. The web-based CM software can provide an opportunity for applying this technique in online and electronic learning environments. Although some research has been done into collaborative CM, most studies were used asynchronous conditions or synchronous FtF collaboration with technology. Thus, with increasing consideration being given to electronic learning, and with the development of web-based CM systems, research is needed to investigate the various aspects of synchronous collaborative CM techniques, both regarding collaborative learning and instruction. In this paper, results of three experimental studies, investigated the application of CM as a knowledge representative tool for synchronous collaborative problem solving via CMC, are reported. Two main issues for investigating synchronous collaborative CM via ICT are addressed in this paper. The first issue was: "can CM, as a knowledge representative mediated tool, be used to enhance synchronous collaborative learning via ICT and, if so, how?" The other issue explored was "which CMC channels are much appropriate for effective collaboration when CM is used as a mediated tool".

2 The First Experiment

As a starting point, the difference between collaborative CM in FtF and ICT groups is c compared (for more information on this experiment see Khamesan and Hammond, 2004a). The main research question is addressed in this study: is collaborative synchronous, web-based, CM as effective as collaborative CM using FtF?

2.1 Method

This study used 2*2 mixed design. The between-subject variable was collaborative CM with two levels, FtF and synchronous web-based via ICT. The within-subject variable was individual CM in two levels, pre-test and post-test. Twenty pairs of participants (13 males and 27 females) volunteered, in response to advertisements distributed by email and notice boards in York University, to take part in the experiment. IHMC CmapTools beta version 3.0 (dsp) was used for CM. Yahoo Messenger version 5.0 was used in ICT group as the communication medium. The written chat room was the only function of this software activated. At the first step of the experiment, participants filled out the personal detail questionnaire were led to experimental rooms. After reading instructions of the experiment, a short training session took place. In this session, the experimenter drew a sample concept map with Cmap software and answered any possible questions related to the experiment and the software. Then participants had 15 minutes to draw an individual concept map (pre-test). In collaborative session, participants' individual concept maps in pre-test were not available. After this step, participants were divided randomly into the two conditions of the experiment. In the first condition, participants used Cmap software to create a concept map with FtF collaboration. They led to a room and worked together on the previous task about the educational system in United Kingdom. In the second collaborative condition, participants were given the same task but in separated rooms. For collaboration, they used the online collaborative part of Cmap, which was web-based CM, and the written chat room facilities of Yahoo Messenger. Participants in both conditions had a maximum of 30 minutes to draw a group CM but were allowed to finish their work as soon as they felt their map was complete. At the end of this session, participants filled out technology, leadership, and awareness questionnaires. The awareness questionnaires were based on one previously developed by Daly-Jones, Monk and Watts (1998) and had two sections, interpersonal awareness (or awareness of others) and personal awareness (or awareness of self). At the final step of the experiment, participants attended a post-test session after 14 days. They were asked to make an individual CM for the same task that they had done in the pre-test as completely as they could by using their experiences from the pre-test and collaborative CM. All

questionnaires items were answered on a 100mm analogue Likert-type scale. The task was a scenario about the introducing the educational system of UK to an overseas student.

2.2 Results

There were not any statistical differences between two groups regarding assessment of technology used in the experiment ($P > .05$). The result shows that there was a statistically significant difference between the time used for group CM between two conditions ($p < .05$). In addition, participants evaluated the role of leader when collaborating through response to two questions "who take the leading role in the constructing the maps?" and "who contribute more knowledge and idea were included in map?" The results show that there was not a statistically significant difference between the two conditions in leading role of constructing the maps and in knowledge that contributed in maps. The first research question addressed here is a comparison between synchronous web-based versus FtF collaborative CM. The data were analyzed with t-test for each measure separately. There were not any significant differences between two-experiment conditions ($df = 18$, $p > 0.05$). The concept maps constructed by the FtF and synchronous web-based via ICT groups were very similar in results of the measures used. The second concern of the experiment was the extent to which the collaborative CM can affect individual learning. The pre-test and post-test had been designed to investigate this issue. The data were entered into a 2*2 mixed ANOVA. The between group factors were collaboration (FtF collaboration versus web-based via ICT collaboration). The within-subject factor was learning effectiveness (pre-test versus post-test). This analysis revealed that the main effect of learning effectiveness (pre-test versus post-test) was statistically significant for all measures, total score ($F (1, 38) = 44.8$, $p < .001$), main node ($F (1, 38) = 22.9$, $p < .001$), supplementary node ($F (1, 30) = 8.5$, $p = .007$) and proposition ($F (1, 38) = 51.1$, $p < .001$). But the group (FtF versus ICT) by individual achievement interaction was not significant for any of them, total score, main node, supplementary node and proposition ($p > 0.05$). In addition, there were not statistically significant differences in interaction level (between group and learning effectiveness) in any of the measures ($p > .05$). In summary, these analyses show learning effectiveness was significantly increased after collaborative CM. They also show there were no differences between conditions of the experiment in learning effectiveness. The second research question addressed in the experiment is a comparison between participants' awareness during collaborative sessions, FtF communication versus communication through text as CMC channel. The data were analyzed with t-test for each measure separately. Participants reported their awareness of their partners on five scales (attention, presence, reaction, understanding and contribution). The results show there was a significant difference between the two conditions. Participants in the FtF group, with the total mean of 83 out of 100, had more interpersonal awareness of their partners than the participants in the ICT group, with the total mean of 71 out of 100. There were statistically significant differences between the two groups in attention and presence ($p < .01$). The participants of the FtF group had better feeling of their partner's presence and more attention to them than the participants in the ICT group. But there were not any statistically significant differences between the two conditions in the other factors of interpersonal awareness, reaction, understanding and contribution ($p > .05$). In the other awareness measure, personal awareness, there were four scales, enjoyment, involvement, attention and interest. The results show there were no significant differences between two means of communication, FtF versus online with text as CMC channel, in means of personal awareness either as a whole or for each measure ($p > 0.05$).

2.3 A Scoring system for Analyzing Collaborative Concept Maps

After analyzing the data of the first experiment, a new scoring system for better understanding of learning effectiveness in collaborative CM was developed (Khamesan & Hammond, 2004). It was on the basis of Stonayova and Kommers's work (2002). Three levels for measuring learning effectiveness are assumed individual learning, the group as a whole, and interaction between individual and group. Each level of learning effectiveness has a numbered sublevel. The results of the first experiment with new scoring system shows in most of measures of learning effectiveness the performance of CMC group was not significantly different from the FtF group, such as individual achievement and creativity, retention, group creativity, rejection measures and overlapping. However, there are some differences between the FtF and CMC groups in measures of transfer. Although there was not a significant difference between conditions in mean of individual to group transfer, in both individual to group and individual to individual transfer measures, FtF condition had better performance than CMC group. It shows FtF collaboration may facilitate the process of conceptual transfer at the group level.

3 The Second Experiment

The second experiment addressed issues regarding CMC channels in a synchronous collaborative CM. In the first experiment, there were significant differences between FtF and ICT with text groups in interpersonal awareness. One solution for improving interpersonal awareness is to use an audio connection as a CMC channel. In addition, a question arises from the experiment one regarding the suitable task for a collaborative problem solving activity with mediating of CM. It seems that a ceiling effect occurred in the first experiment with regard to the task (educational system in Britain). As the task is an important factor in any collaborative learning activity and can hinder the effect of collaboration, changing the task may give a clearer idea about the effect of collaboration. Thus, two main questions that addressed in this experiment were: "what is the effect of CMC channels (FtF versus ICT with text versus and ICT with audio/text) on personal and interpersonal awareness in synchronous web-based collaborative problem solving with mediating of CM via ICT?" and "does the type of CMC channel affect learning effectiveness in a synchronous web-based collaborative CM on a problem-solving task?"

3.1 Method

This study used a between-subject design. The between group manipulation was the kind of CMC channel [with three levels: online with written chat (text) versus online with audio and text connection versus FtF]. Dependent variables were "awareness" and "learning effectiveness". Thirty pairs of participants (12 males and 48 females) volunteered, in response to advertisements distributed by email and notice boards in York University (UK), to take part in the experiment. The software, instructions and questionnaires were the same of the first experiment. The procedure of the experiment also was similar to the first experiment except to the post-test session. A pilot study was conducted for choosing appropriate task for a collaborative CM. A pilot study was conducted to choose a suitable task.

3.2 Results

The interpersonal awareness data were entered into a one-way ANOVA. The results show there were statistically significant differences among the conditions in the means of attention ($F(2, 57) = 7.177$, $p = .002$), reaction ($F(2, 57) = 9.106$, $p = .001$) and total score of interpersonal awareness ($F(2, 57) = 6.268$, $p = .003$), but there was not a statistically significant difference among the groups in presence and understanding ($p > 0.05$). In addition, there was no significant difference in perceived contribution ($F(2, 57) = .120$, $p = .888$). The results of a Tukey's HSD test showed that in attention and total score of interpersonal awareness the different was statistically significant between FtF and audio/test group ($p < .05$). In reaction, the audio/text group was significantly different from both the FtF and the text group ($P < .05$). The participants in the audio/text group reported lower awareness ratings than those in the FtF and text groups for attention, reaction and total interpersonal awareness. On the other hand, the results showed there were no statistically significant differences among the conditions for any of the measures of personal awareness ($p > 0.05$). Each participant constructed one individual CM, at pre-test, and a group CM with his or her partner in the collaborative session. Overall, 90 concept maps were constructed in the experiment. The total number of concepts in the individual concept maps (pre-test) gives an indication of the participants' knowledge on the task before the collaborative session. The results show there was not any significant difference among the groups in means of participants' knowledge (base level) on the task ($p > 0.05$). In addition, the total number of concepts in the group concept maps shows the group achievement. The results show there was not any significant difference among the groups in mean of group achievement ($p > 0.05$). The total number of concepts in the group concept maps that are not in either of the individual concept maps shows the group creativity. The results showed there was not any significant difference among the groups in creativity ($p > 0.05$).

3.3 Follow-up Experiments

In a follow-up experiment, the effect of a high quality of audio connection was investigated. The experiment investigated an unexpected result from the second experiment regarding the lower learning effectiveness and interpersonal awareness of the audio/text group. One hypothesis for this unexpected result is the low quality of audio/text connection. In this experiment, I added a high-quality audio (a sound mixer instead o using online software) to the previous study. The experiment revealed there were significant differences in interpersonal awareness between low and high quality of audio/text groups. On all measures of the scale used, participants in high quality of audio/text had higher awareness of their partners compared to participants in low quality of audio/text

group. Furthermore, the experiment results shows with higher quality audio connection the learning effectiveness does not rise necessarily. On the other hand, although there was not a reliable difference amongst the conditions in learning effectiveness measures, high quality audio/text group had lower group achievement and creativity not only than FtF but also than ICT groups, text and low quality audio/text. One explanation for these trends is that participants usually engage more in social collaboration when they use audio as CMC channel than other kind of communication methods. This results reveals text as CMC channel could make better learning environment in synchronous collaborative CM because it causes more focus on the collaborative task than other CMC channels.

4 The Third Experiment

With the potential of digital networks, different group interactions for collaborative problem-solving task with mediating of CM via CMC can be manipulated. I designed three different scenarios, on the basis of Stonayova and Kommers's work (2002), investigated for interaction. *Shared Interaction* was used in the previous experiments where both members of a group built the group concept map simultaneously. In this condition, each member of the group can see any changes of the group concept map that are made by his or her partner, on his or her screen. They have a CMC channel for communication. In *Moderated Interaction,* at the beginning of the collaborative session, participants discuss the task and decide who would be editor (leader or facilitator) of the group. The editor of the group is responsible the building and editing the group concept map. The other member of the group is able to see any changes of the group concept map on his or her screen and gives his or her comments to the editor, but is not able to edit the group CM. They have a CMC channel for communication; and *Distributed Interaction* is a non-web-based interaction. Each member of a group is allowed to edit the group concept map intermittently. At the beginning of collaborative session, members of the group discuss the task and decide who starts building the group concept map. They also decide when shared concept map should pass to other member of the group. During the period when a member of the group is drawing the group concept map, other member of the group have access to the last concept map that he or she drew and passed to his or her partner. This may facilitate the process of thinking about the map. They have a CMC channel as well. In conclusion, this experiment gives consideration to using different modes of interactions for synchronous collaborative CM via CMC with three main questions. Firstly, does web-based collaborative CM via CMC affect learning effectiveness in comparison with non web-based collaboration? Secondly, which kind of group interaction in synchronous collaborative CM via CMC is work effective for learning? And thirdly, does web-based CM affect the participants' personal and interpersonal awareness in comparison to non web-based interaction? The hypotheses of the experiment are "web-based collaborative CM enhances learning effectiveness and awareness in comparison with non-web based collaboration" and "shared interaction enhances learning effectiveness in comparison with other interactions".

4.1 Method

This study used a 3*2 mixed design. Between group manipulation was the mode of interactions in synchronous collaborative problem solving CM via CMC (with three levels: shared, moderated and distributed interaction). The within-subject variable was learning effectiveness in individual concept map at two levels, pre-test versus post-test CM. Twenty participants, ten groups, served in each condition. All were the students of York University (age between 18 and 27 with mean of 19.9 years). There was no significant difference regarding the age of participants among the conditions ($p > 0.05$). The procedure of the experiment was essentially the same procedure of the first experiment, with the exception of different conditions. After the pre-test session, participants were divided randomly into the three conditions of the experiment, shared, moderated and distributed interactions. Participants had up to 40 minutes to draw a group concept map but were allowed to finish their work as soon as they felt their map was completed.

4.2 Results

Awareness: Although participants' interpersonal awareness in distributed interactions was lower than other conditions in most of measures, the results show there was not a statistically significant difference among the three conditions in the means of interpersonal awareness ($p > .05$). Overall means of interpersonal awareness in shared, moderated and distributed interaction were respectively 84, 82 and 75 out of 100. There was not a significant difference among the conditions in contribution measures either ($p > .05$), although the contribution of moderated conditions is lower than other interactions. In addition, the results show there was not a statistically significant

difference among three conditions in the means of personal awareness ($P > .05$). Overall means of personal awareness in shared, moderated and distributed interaction are respectively 82, 78 and 78 out of 100.

Learning effectiveness at individual level: Learning achievement in collaborative CM is based on the total number of concepts. A comparison between the total number of pre-test and post-test can show individual achievement following a collaborative session. The data was analyzed with 3*2 mixed ANOVA with main effect of individual achievement in two levels, pre-test and post-test and between-subject factor of mode of interaction. The results showed there was a significant difference in main effect of group achievement (individual CM in pre-test and post-test) ($F (1, 55) = 177$, $p < .001$). But the group (mode of interaction) by individual achievement was not significant ($p > .05$). In addition, total number of concepts in post-test concept map consists of two parts: knowledge acquisition and retention. Knowledge acquisition is a measure of the number of new concepts in the post-test which are not in the pre-test. It includes concepts transferred from the group CM and individual creativity (new concepts that were neither in the pre-test concept map nor in group concept map). Retention indicates concepts that are transferred from a participant's pre-test concept map to his or her post test concept map. The results show there was a statistically significant difference among the conditions in means of participants' knowledge acquisition ($F (2, 53) = 3.61$, $p = .034$). The result of Tukey HSD shows the distributed interaction group has significantly higher score than both shared interaction ($p = .05$) and moderated interaction ($p = .034$). On the other hand, the analysis on individual creativity and retention measures show there was not a statistically significant difference among the conditions in means of participants' individual creativity and retention ($p > .05$).

Learning effectiveness at the level of the group as a whole has three measures: group achievement, group creativity and structure and configuration. The total number of concepts in the group concept maps shows the group achievement. The data was entered to a one-way ANOVA. The results show there was not a significant difference among the conditions in mean of group achievement ($p > .05$). The total number of concepts in the shared concept maps that are not in either of the individual concept maps (in pre-test) shows the group creativity. The results show there was not a significant difference among the groups in mean of group creativity ($p > .05$)

Learning effectiveness at the level of interaction between individual and group has six measures: rejection at the group level, rejection at individual level, individual to group transfer, group to individual transfer, individual to individual transfer and overlapping. The results showed although there was not a significant difference among the conditions in number of transferred concepts from individual concept maps to the group concept map ($p > .05$), there was a significant difference among the group in concepts transferred from the group concept map to individual concept maps in post-test ($F = (2, 53) = 5.31$, $p = .008$) and individual to individual ($F (2, 53) = 5.47$, $p = .007$). The result of Tukey HSD showed the distributed interaction group, with mean of transferred concepts from the group concept map to individual post-test of 12, has significantly higher score than both shared interaction ($p = .01$) and moderated interaction ($p = .033$). In addition, the result of Tukey HSD for individual to individual transfer shows the distributed interaction group has significantly higher score than both shared interaction ($p = .018$) and moderated interaction ($p = .014$). For rejection at the group level (concepts from the pre-test concept map that are not transferred to the group concept map) and rejection at individual level (concepts of the group concept map that are not transferred to the post-test concept maps) the data was entered to one-way ANOVA. The results show there was not a significant difference among the groups in number of rejected concepts both at group level and individual level ($p > .05$). Overlapping between partners' concept maps in pre-test and in post-test can be considered as the effect of collaboration. The data was entered into a one-way ANOVA. The results show there was a significant difference among the conditions in means of concepts that were overlapping ($F (2, 53) = 5.81$, $p = .005$). The result of Tukey HSD shows the distributed interaction group has significantly higher score than both shared interaction ($p = .007$) and moderated interaction ($p = .025$).

5 Summary

5.1 Using CM as mediated tool to enhance synchronous collaborative learning via ICT

The first experiment of the thesis compared collaborative CM in FtF versus via ICT groups. The experiment revealed that the technology, i.e. Cmap, had an acceptable level of performance, both in individual and collaborative CM and both in FtF and ICT groups. The results also showed the collaboration results in learning, both at individual and group levels. That proves new technologies, based on ICT, can create a learning effectiveness environment as

effective as FtF and CM can be used as a collaborative mediated tool for synchronous collaborative problem-solving via ICT. Following the results of the first experiment, learning effectiveness was investigated in different modes of interactions in synchronous collaborative CM via ICT. The potential of digital networks allows us to manipulate different group interactions. It is important because technical problems are a main obstacle for any online collaborative learning and using high quality and rich digital environment in many situations is not cost effective. Knowing which online interaction provides more effective learning can help in choosing the best combination of technologies and learning strategies in a synchronous collaborative CM via ICT. Thus three different group interactions and sharing knowledge were designed and compared: shared interaction, moderated interaction and distributed interaction. The results highlighted the role of non web-based CM in synchronous collaborative learning via ICT. The experiment showed the role of distributed interaction both in learning effectiveness at the group level and at the level of interaction between group and individual. Participants in distributed interaction made more concepts in their group CM and also had considerably more new concepts in their group CM than other conditions. It suggests that the process of collaborative learning is facilitated more in this kind of interaction and also may indicate that a web-based interaction is not the most effective facility for synchronous collaborative CM via ICT in term of learning effectiveness at the group level. At individual level, difference between participants' pre-test and post-test, the results revealed the mode of interaction is not an effective factor for individual achievement. However, knowledge acquisition in distributed interaction was significantly higher than web-based interaction. In addition, the results showed the distributed interaction was also able to transfer more concepts from group CM to individual CM in post-test than other conditions.

5.2 Appropriate CMC for effective synchronous collaborative CM

The second issue was addressed in the thesis was the appropriate type of communicational media that is needed for a synchronous collaborative CM via ICT. Using ICT for learning and teaching cannot be imagined without using CMC channels because collaboration and exchanging knowledge and idea is an inseparable part of any collaborative learning and teaching program. Therefore, for investigating any online learning technique we need to investigate which communicational medium can create better communicative environment and, subsequently, more effective collaboration and learning outcome. For evaluating the appropriate CMC channel, I measured participants' interpersonal and personal awareness during collaborative session. The theatrical and empirical literature shows that awareness plays an important role in an effective collaboration. The assumption for using awareness measures was: "having knowledge of group and individual activity has central role in collaborative activity". In the first experiment, the participants' awareness in ICT group with text as CMC channel was compared with FtF group. Although there was not a significant difference between conditions in means of measures of the personal awareness, the participants of FtF group reported significant higher level of interpersonal awareness than participants in ICT condition both in the whole interpersonal awareness scale and in factors of attention and presence. The result of interpersonal awareness in FtF condition was probably because of physical presence. The differences between the two conditions also show web-based facilities with a written chat room cannot create a collaborative environment which exactly matches the FtF environment. In addition, the results may be considered as an explanation for the lower transfer measure in ICT group in comparison with FtF and show the effect of CMC channel on the learning outcome. Although these results show a web-based collaborative CM, like Cmap, can create a suitable collaborative environment for CM because it can affect most collaborative factors that are essential for creating an acceptable group CM (e.g., understanding, contribution, and reaction), more investigation needed to show which CMC facilities could minimize the differences between FtF and ICT conditions in awareness and created a collaborative environment which could compensate for the lack of physical presence. I explored this issue in the second experiment with comparing FtF collaboration with two ICT groups, online with text and online with text/audio, with a different task (university campus) and more time for collaboration (40 minutes). Surprisingly, the results did not match with what we had expected and also was inconsistent, with the results of text condition in the first experiment. I had expected with providing richer CMC channel and more time for collaboration, the measures of interpersonal awareness in text/audio condition increased as much as FtF condition whilst the participants of the text/audio group showed lower awareness of their partners, in attention and reaction. The results do suggest that the addition of an audio channel may not always improve interpersonal awareness, and may even degrade it. I supposed these unexpected results was the effect that an artifact caused by some sort of degradation of Cmap performance when Yahoo audio was used at the same time. This possibility was explored in another study (section two, chapter four). The experiment approved our hypothesis because there were significant differences between low and high quality of audio/text groups in interpersonal awareness. In addition, although it was not reliable, participants of high quality of audio/text group had better awareness of their partners than text group and as nearly the same level as FtF group. It

shows with a shared workplace, having an audio connection channels does not lead, necessarily, to better interpersonal awareness. In the other follow-up experiment, I investigated the effect of time on interpersonal awareness when text used as a CMC to investigate the inconsistency between the results of the first and second experiments, in the text group. The results showed with increasing the time of collaboration participants reported higher interpersonal awareness. The experiment revealed the time of collaboration is an effective factor in awareness of other in synchronous collaborative CM via text as CMC channel. In conclusion, with the current task at least a forty-minute collaborative session is essential in synchronous collaborative CM for creating an interpersonal awareness between participants as well as a FtF collaboration. On the other hand, the results of the last experiment showed participants in web-based interaction had better interpersonal awareness than non web-based interaction, although the results were not statistically reliable. Thus, the results suggest that the mode of interaction may be a factor for interpersonal awareness in collaborative CM via CMC along the kind of CMC channel.

6 References

Baroody, A. J., & Bartels, B. H. (2000). Using concept maps to link mathematical ideas. *Mathematics Teaching in the Middle School*, **5 (9)**, 604-609.

Cañas, A. J., Ford, K. M., Novak, J. D., Hayes, P., Reichherzer, T. R., & Suri, N. (2001). Using concept maps with technology to enhance collaborative learning in Latin America. *The Science Teacher,* **68**, 49-51.

Chiu, C. H., Huang, C. C., & Chang, W. T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computer & Education,* **34**, 17-25.

Chung, G. K. W. K., O'Neil, H. F. J., & Herl, H.E. (1999). The use of computer-based collaborative knowledge mapping to measure team processes and team outcomes. *Computer in Human Behavior*, **15 (3-4)**, 463-493.

Daly-Jones, O., Monk, A.F. & Watts, L.A. (1998). Some advantages of video conferencing over high quality audio conferencing. International Journal of Human-Computer Studies, **49**, 21-59.

De Simone, C., Schmid, R. F., & McEwen, L. A (2001). Supporting the learning process with collaborative concept mapping using computer based communication tools and process. *Educational Research and Evaluation,* **7(2/3)**, 263-283.

Herl, H. E., O'Neil, H. F., Chung, G. K. W. K., & Schachter, J. (1999). Reliability and validity of a computer-based knowledge mapping system to measure content understanding. *Computers in Human Behavior,* **15**, 315-333.

Khamesan, A. & Hammond, N. (2004a). Synchronous collaborative concept mapping via ICT: learning effectiveness and personal and interpersonal awareness. In Cañas, A.J., Novak, J.D., & Gonzales, F.M. (Ed.), *Concept maps: Theory, methodology, and technology*, Proceedings of 1st International Conference on Concept Mapping (CMC), Spain, Vol. (2), 385-395.

Khamesan, A. & Hammond, N. (2004b). Taxonomy of analysis levels of learning effectiveness in collaborative concept mapping. In Cañas, A.J., Novak, J.D., & Gonzales, F.M. (Ed.), *Concept maps: Theory, methodology, and technology*, Proceedings of 1st International Conference on Concept Mapping (CMC), Spain, Vol. (2), 231-234.

Komis, V., Avouris, N., & Fidas, C. (2002). Computer-supported collaborative concept mapping: Study of synchronous peer interaction. *Journal of Education and Information Technologies*, **7(3)**, 169-188.

Suthers, D.D., Hundhausen, C.D. & Girardeau, L.E. (2003). Comparing the roles of representation in face-to-face and online computer supported collaborative learning. *Computer & Education*, **41**, 335-351.

Stoyanova, N., & Kommers, P. (2002). Concept mapping as a medium of shared cognition in computer supported collaborative problem solving. *Journal of Interactive Learning Research,* **13(1/2)**, 111-133.

Van Boxtel, C. V., Van Linden, J. V. D., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction,* **10(4)**, 311-330.

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THE CONCEPT MAP AS A COGNITIVE TOOL FOR SPECIALIZED INFORMATION RECALL

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Abstract. The present article discusses some aspects related to the process of text analysis with a concept map aiming at structuring textual knowledge and achieving a better recall of information in the context of teaching technical translation. The concept map is considered not as a system for representing knowledge structures of domains, but as a cognitive means used as a method for text analysis in specialized fields. The paper reports data from a research project in which the author carried out an experiment on two groups: the 1st group analyzed the text by extracting its data in the form of a concept map, whereas the 2nd group proceeded using the traditional tool of text analysis. The two groups were later subjected to recall tests; free recall and recall by questionnaire. One very consistent finding shows that the use of the concept map as a tool of text analysis helped not only in retaining the main information units of the text, but also in recalling textual units in defined semantic categories.

1 Introduction

The referential basis of this paper is a study by the author on knowledge representation in both reading and translation tasks and its effects on knowledge acquisition and development in specialized fields. In bringing the translation learner to the expert level, we argue that performance can be improved when the methods and strategies are specifically targeted and taught. This paper sets out to briefly develop the use of concept maps as a means to cognitively maximize and structure domain-specific knowledge and hence guarantee better integration and retrieval of information in specialized texts. The study is part of an ongoing thesis research project at the School of Translation and Interpretation, *Ecole de Traduction et d'interprétation* (ETI), and joins a series of studies being presently launched by this institution with the purpose of developing the empirical research base in translation and interpreting studies. It aims at improving professional training in specialized fields to keep pace with the increasing demand for highly-qualified specialized translators. The massive quantity of information available in real or cyberspace obliges trainers to conceive innovative training methods that provide students with consistent strategies or techniques to approach the considerable mass of fragmented textual materials. Introducing concept mapping as a synthesis instrument is believed to facilitate the management of information written in expert language. In this sense, the use of concept maps may help students in specialized translation courses to distinguish the essential from the accessory when processing domain-specific texts and to acquire instrumental skills for "meaningful learning". In fact, the concept of "meaningful learning" implies that we learn new knowledge by relating new concepts to a network of concepts we already know. Therefore, learning meaningfully means being aware of the nature of relationships we define between objects or facts when integrating them into the existing knowledge base. Consequently, information is being stored in specific organized blocks. Contrary to rote learning, where new information is integrated without defining links between old and new information, the construction of knowledge through concept representation may lead to more efficient storage in memory and superior retention over time compared to retention of unrelated descriptions of a topic.

Over the last three decades work in the psychology of language has focused on the description of cognitive structures and processes of language comprehension and production (Bereiter and Scardamalia, 1987; Gernsbacher, 1990). In textual linguistics, it is assumed that understanding a text implies constructing a mental representation of its meaning. A reader builds a mental representation of the text content when reading (Britton and Graesser, 1996; van Dijk, 1997; Kintsch, 1998): *"A reader's resultant mental representation of a text is not a mere copy of the text with its linguistic structures, but converts the text form from a linguistic object to a conceptual object"* (Van Dijk, 1997, 18). One effective method to reach a coherent mental representation for encoding and retrieving information is to rely on the structure of the text (Meyer, 1975; Meyer and Poon, 2001). A skilled reader tends firstly to extract from a text a conglomerate of highly important units of information in order to construct the abstract mental representation of the text (Langacker, 2001). In this way, discourse features and other linguistic signals are considered as *"a kind of temporary scaffolding, put up in stages in order to construct a more permanent consolidated structure"* (Langacker, 2001, 181). Due to working memory constraints (Baddeley, 1992), it is not possible for a reader to retain everything in a text, therefore *"some information more than others must be selected for deeper encoding and more cycles of processing or elaboration"* (Meyer and Poon, 2001, 141).

The study of professional communication has brought new insights into the nature of linguistic skills and shown how expertise is acquired through knowledge organization and reorganization and not only by way of a steady accumulation of information (Swales, 1990; Ericsson and Kintsch, 1995; Moser-Mercer, 2000). We know that experts are able to perform domain-specific tasks at a level consistently superior to the performance of non-experts. We also know that experts develop, through extensive practice, domain-specific skills that allow them to extend their working memory ensuring fast and reliable performances (Ericsson and Kintsch, 1995; Baddeley, 2000). Empirical findings in the cognitive field have confirmed the positive effects of knowledge organization and cognitive representations on information memorization (Schenk et *al.*, 1998). These positive consequences are determined by a higher availability of information when processed in a structured representation. Cognitive representations can, therefore, guarantee information conservation and knowledge systematization. Extending these findings to the translation field, empirical studies have shown that qualitative differences in translation performance between experts and novices were the result of the former's superior knowledge organization structures associated with the translation task (Wilss, 1996; Moser-Mercer, 2000; Jarvella et *al.*, 2002; Shreve, 2002). Thus, much depends on how things are cognitively arranged, represented, and stored in or retrieved from memory (Shreve, 1997, 161). In other words, professional translators are aware of developing strategies and working methods when translating and do not simply rely on the quantity of information they know.

Considering that translation involves, firstly, a particular type of text comprehension, the notion of mental representation serves as a major translation goal knowing that mastering translation is equivalent to extracting and retaining from a text the essence of its meaning in order to transfer it to the target language. However, the distinction between important and less important information is dependent on the type of textual content and its relation to the specialized field. In a specialized context, mental representations are basically conceptual and constructive, because the objects of interest are conceptual systems. Therefore, the reader is bound by a presupposed discourse type, in form and content, that is to say by linguistic and conceptual features, because the text type is governed by established norms and realities leaving little space for the reader's interpretation. Consequently, the construction of a translational mental representation of a text in a technical domain, for example, calls for a map that contains information on technical concepts. The resultant map regards features of the text in its relation to the technical context within which the text is formulated. Accordingly, one assumption would be that the permanent structure in a specialized field refers to a unit of a conceptual representation belonging to a global conceptual system. For this reason we refer to mental representations as conceptual representations. Applying the notion of conceptual representation by means of concept mapping, for instance, could help improve the quality of information extraction and text comprehension. We chose to limit the current study to a specialized field for two specific reasons: not only does specialized discourse seem to be situated at the borderline of expert knowledge and "fuzzy" knowledge, the latter including various discourse aspects such as style, rhetoric (typical metaphors), discursive structures (text patterns; methods of proof and demonstration); but it also, and essentially, deals with conceptual information in an organized manner that is articulated within the representation of conceptual systems. In this way, specialized texts refer to concepts which have been classified and defined by experts in their field of performance (Van Dijk, 2001, 8). Whether the reader manages to construct a congruent model of the text depends on how coherent she/he can make use of the information contained in the text. The reader who does not possess the knowledge of the expert needs to have access to the relevant knowledge in order to understand the text and be able to translate it. She/he should have an adequate mental model of the technical field dealt with to be able to understand and maintain the appropriate connections between the text and its domain of reference. Since comprehension involves the abstraction of information from the linguistic form to integrate it in a abstract form, this process entails many cognitive sub-processes ranging from problem resolution (trial, hypothesis, error) to decision making (confirmation, conclusion), implying the involvement of some domain-relevant tasks or language-processing strategies.

2 Strategies for Translation in Reading Phase

Considering the fact that translation is a complex activity that comprises many sub-skills; reading-comprehension-writing, reasoning, problem solving, decision making, attention and recall, etc. (de Groot, 2000), it seems logical to start analyzing the translation process at the very beginning, i.e. at the level of the reading process. Any strategy to be envisaged for taking translation decisions would have to be based, to a large extent, on the quality of the input process, i.e. the reading comprehension process. Research on reading indicates that any outcome of text processing is determined by the level of understanding needed for an optimal performance and the extent to which one is able to derive information from the text and coordinate it with the reader's existing cognitive representations. This

assumption holds true as long as verbal material can successfully access an integrated conceptual representation in the memory system. The fact is that cognitive studies admit that one of the principal factors responsible for comprehension in reading is the knowledge stored in long-term memory and the way this knowledge is transferred to working memory as new information interacts with existing information. In language processing, there is an assumption that activation input, through reading for example, relates to networks assembled in long-term storage. These connections are thought to include lexical representations, word order patterns, conceptual/functional representations that represent communicative intentions or meanings (MacWhinney, 1997). Other memory structures related to procedures (strategies, tactics), representations of textual schemata, concept structures, etc., are supposed to be implicated in input activation. There are many strategies to represent a problem in a specific situation. One of the most frequently used in enhancing memory capacity and visualizing the problem from different vantage points is the strategy of classification by categories. This classifying strategy uses tools ranging from visual maps, semantic networks, hierarchical schemata, etc., and intensifies specific cognitive skills such as analysis, comparison, inductive and deductive reasoning, and thus improves comprehension. We propose that the conceptual mapping technique is a means to allow for mental knowledge organization by delimiting the conceptual framework of a domain through the identification of links between different concepts. We believe that this type of concept arrangement may facilitate not only the acquisition of structured knowledge, but also the retrieval of mentally linked concepts and benefit the recall of information. For technical texts, the introduction of concept mapping as a cognitive strategy during the reading process might lead to a better representation of their conceptual contents and, more specifically, enhance the process of knowledge construction for the development of expertise in specialized fields.

2.1 The Concept Map; a Mental representation Tool

Many studies investigated concept maps as information research tool (Kommers et *al*., 1992; Kremer and Gaines, 1996; Debourges et *al*., 2001). From a communication perspective, the emphasis is put on the efficiency of cartography to synthesize complex realities in a new composite world represented as a complex network of information. Such representations bring out the complexity of relations that characterize information superhighways, as we are developing schemata in trying to "come to grips" with the knowledge industry. Concept maps can also detect common ideas that are implicit and help reorganize information that needs to be communicated (Lemire et *al*., 1998). In that sense, the representation of sets of concepts or ideas highlighted in a map is not normative and the linkage between concepts is not predetermined. Accordingly, a concept map is not comprehensive. It describes the knowledge structure of an individual, expert or novice, on one specific theme: *"concept maps are represented as one way to synthesize the conceptual structures of individual experts in a domain and describe this expertise in a visual and coherent manner"* (Lambiotte et *al*., 1989). For that reason, it is sometimes employed to underline the differences between novice and expert performances. Therefore, it is important to keep in mind its highly individual nature.

From a cognitive perspective, the concept map has been used as a psychological artifact or instrument to structure, guide and, if needed, transform knowledge on the basis of socio-cultural and psychological traditions. Hence, as a learning aid, several experiments directed at improving learning were carried out in various situations and for specific purposes; evaluating program courses (Thomson, 1997); eliciting experienced mentor teachers' practical knowledge (Zanting et *al*., 2003); analyzing the presentation of concept descriptions in textbooks (Wu et *al*., 2004); developing and sharing training materials destined to the interpreter trainers' community (Moser-Mercer et *al*., 2005). In this context, the benefit of concept mapping rests on its mediating feature as cognitive scaffolding that sets a specific aim for the activity to be achieved (by selecting concepts and defining the linkages between them); determines the schema that needs to be developed in order to achieve this aim (by representing the conceptual set), and offers an opportunity to choose the means for achieving this aim (by making a deliberate choice of nodes and their relationships according to how they are perceived). In view of all these considerations, concept mapping represents a method of work that emphasizes awareness and familiarity with the nature and structure of the problems encountered. This aptitude refers to the notion of *deliberate practice* which explains, in the literature on expertise, the experts' superior performance, because it mediates the development of skills for knowledge acquisition rather than represent aggregate experience. In a way, concept mapping provides for ongoing pattern learning whose aim is the identification of meta-knowledge, its representation and storage. This orientation brings us back to one of the most important ideas in Ausubel's theory stating that the storage of information in the brain is highly organized with linkages formed between various older and newer elements. This cognitive structure

represents a framework for organized concepts which are the individual's representations of sensory experience (Ausubel, 1968, 506).

In the field of specialized and technical translation, every one agrees that prior domain-specific knowledge is crucial for ensuring a high level of translation quality. In addition to the fact that translators must take into account the translated text in accordance with the norms governing a specific translation situation and the pertinent value of its information, they are involved in the coherent construction of discourse itself. This is made possible through the construction of knowledge of the specific field and through existing knowledge. This is further support for the cognitive view of learning defended by Ausubel who stated that: *"The most important single factor influencing learning is what the learner already knows"* (Ausubel, 1968, vi). For that reason, we borrow the notion of concept mapping that has proved effective in the educational field (Ausubel, 1968, Novak and Gowin, 1984) and apply it as a specific-domain knowledge structuring tool and as an aid for information recall. Consequently, we see concept mapping as an efficient tool and strategy to be used in specialized translation training. The following have been taken as working guidelines: *"The recall of previously learned and known ideas – the individual thinking "What do I know about {x}?...The recording of new ideas as a result of some learning situation…An individual "thinking about" some already known idea or ideas in response to some event or situation"* (McAleese, 1994, 9). On the basis of these arguments we have chosen to include the cognitive process of recall as an integral part of learning. Our experiment focuses on the influence of concept map construction on the reader's ability to retain specific-domain information contained in a technical text.

3 The experiment

This concept mapping study explores concept representations in text processing through the use of concept maps as a cognitive tool. The study analyzes students' retention performance after having been trained to construct concept maps. We hypothesize improved recall of specialized concept representations at the end of training on text analysis with concepts and, after practice, more efficient knowledge construction. More specifically, we will discuss the performance of students in recalling the main information extracted from technical texts. "Main information" is considered to be information units that meet the criteria for main information set by the instructor. We considered the following criteria as measures to evaluate recall performance for both groups:

- Number of information units recalled in general,
- Number of main idea units recalled,
- Degree of cohesion between information units

Answers were examined according to their fit with the information units defined in the conceptual grid.

3.1 Method

We believe that the process through which a cognitive tool is appropriated and mastered by a student is not a simple task. It is a rather demanding process which requires extensive training and controlled practice (O'Malley and Chamot, 1990; Wertsch, 1998); *"Because strategies are complex skills, a person attempting to apply an unfamiliar strategy to a demanding task will have difficulties in controlled processing that can be anticipated from performing two complex tasks simultaneously. It is for this reason that teaching students to use new strategies with cognitive tasks is extremely difficult"* (O'Malley and Chamot, 1990, 52). Despite the fact that we initially had planned for a study period lasting several months, we could not mobilize the same participants for a period exceeding one month.

3.1.1 Participants and Material

A representative sample of 14 francophone students (7 females and 7 males) studying at the School of Translation, University of Geneva, participated in the experiment. All of them have a very good level of English as a second language. In spite of that, we introduced a Likert type test composed of nine questions to assess their perceptions of training and to test their perceptions of text difficulty, background knowledge, motivation, importance, clarity of arguments, organization, etc. For example, for difficulty assessment, the question asked is: How difficult did you find the text to read and understand? For quality assessment, the question was: How would you assess the level of your background knowledge in this text? The answers were rated on a scale from one to five. For example, to

measure quality, answers were rated on the following scale: Very good, Good, Barely Acceptable, Poor, Very poor. As far as the linguistic part of the Likert test is concerned, the results of the test showed that despite the complexity of specialized knowledge, answers reflect general comprehension of all texts. Subjects could choose to answer in French or English; this was done in order to exclude any linguistic reason that might hamper the recall of information. The participants were selected from two different curricular phases of the translator training program; 1st and 2nd cycle. They were divided into two groups (Gr.A and Gr.B).

Two technical-scientific texts, one on the *Watch,* the other on the *Brain*, were submitted during the last session of training to Gr.A and Gr.B for analysis using either the concept map technique or the traditional text analysis technique. These texts were then the object of free recall and questionnaire recall tests. Both texts represent a granular description of the aforesaid notions (Watch and Brain) and were prepared to have identical content structure with approximately the same number of idea units; 36 for the *Watch* text and 37 for the *Brain* text. But they had different content, that is to say lexical units specific to text and not exactly the same types of relations between idea units. For that, they were prepared according to an analysis grid divided into conceptual categories ranging from the most important segment of the text analyzed to the less important. Each segment was referred to by the type of its conceptual class defined by its links with surrounding lexical units. A conceptual framework was then developed regrouping concepts of each text according to their conceptual category. For the *Watch* text, the concept of *"mechanical watch"* comprises, for example, the following:

- Mechanical watch(Part) = mainspring, gear train, escapement
- Mechanical watch(Spec) = self-winding watch, complicated watch

"Part", holds for the category designating the parts of the watch. *"Spec"*, holds for the conceptual category referring to different types of this watch, etc. As for *Brain* topic, the concept of *"cerebellum"* comprises the following:

- Cerebellum(Func) = coordinating movement
- Cerebellum(Prop) = 10% of the brain weight

"Func", is the category referring to its function. *"Prop"*, refers to its characteristics, etc.

3.1.2 Procedure: training and recall tests

Participants were introduced to the technique of conceptual representation (either concept mapping or traditional text analysis techniques) for a period of four weeks. Recall tests were administrated two days after the end of the first part of training without any prior notice. The entire experiment involved two experimental design-components. During the first phase, group one (Gr.A) was introduced to the technique of concept mapping for analyzing technical texts after reading. Gr.A was given theoretical material on concept mapping followed by text analysis exercises. They constructed several maps individually by analyzing expository technical texts of about 400 words each. They were asked, for instance, to find the key concept in the text and determine its links with other associated concepts; or, to select different linking words (*marqueurs linguistiques*) and define the conceptual category to which they belong; etc. Under the same conditions, the second group (Gr.B) performed text analysis in a traditional fashion, that is to say, by breaking down a text into ideas. Gr.B proceeded by dividing the texts into paragraphs and extracting major, secondary and tertiary ideas.

Experimental Group	Presentation of method I	<u>TEST 1</u> : 2 weeks after training on method I	Presentation of method II	<u>TEST 2</u> : 2 weeks after training on method II

Table 1: Experimental Design

For reasons of counterbalancing, the groups were inversed and the same measures were repeated for Gr.B. during the second phase of the training.

After a month of training, the two groups (Gr.A and Gr.B) were subjected to recall tests: free recall and recall by questionnaire. The free recall test was administered first. Subjects were asked to recall, in the form of continuous writing and not as separate ideas, the content of the text they had analyzed two days prior to the recall test. They were asked to write down all the information they could remember from the text, using their own words if they could not recall the exact term. In case they remembered an idea but not how it was related to other idea units, they were invited to explain the idea and not simply write down the word. The test lasted 20 minutes. Recall data was scored according to the presence or absence of idea units as compared to the original text. As for the questionnaire, seven conceptually-oriented questions were asked. Following are examples of some of the questions:

- What are the different types of a mechanical watch as mentioned in the text? (*Spec*) Give one main characteristic of each type (*Prop*)
- Name at least two parts of the analog quartz watch? (*Part*)
- How would you define a watch with analog display? (*Prop, Part, ...*)

Recalled information was scored for accuracy in accordance with idea units of the text. For the purpose of this article, we focus our discussion on the results of the 1st phase of the experiment; Gr.A/concept mapping technique *vs*. Gr.B/traditional analysis technique.

3.2 Results and Discussion

The mean of remembered ideas by each subject was computed. The mean of the total recall for both groups was also computed. We present here the average of the recall scores of our results: the recall average for Gr.A, the first one to be initiated to the concept mapping technique, as established through questionnaire is 50.5% of the text value (as established by the instructor). The value of recall did not exceed 35% of information remembered within the same group (Gr.A) after having analyzed a text with traditional text analysis tools (text division into paragraphs and ideas). One interpretation of the results is that when the specialized content was not familiar, Gr.A subjects mentally represented the network of concepts drawn from the text in an organized way and recalled more ideas. The definition of the nature of links between concepts helped with the retrieval of idea units. On the other hand, Gr.B who used the traditional text analysis first, recorded an average of recall of only 36.42%, with a slight improvement of recall (42.85%) when applying the concept mapping technique. This improvement in recall may be explained by the fact that with a specialized unfamiliar content, Gr.B subjects used the concept map as an organizational and explicit strategy for text analysis. They selected from memory the representation they used as an overall structure processing defining main concepts and the nature of their relations. Their attention became more focused on specific concepts than on linguistic units and recalled more information. This interpretation was backed by the comments collected from the subjects after the recall tasks. We have noticed the same recall tendency in the free recall results - a better performance for Gr.A than Gr.B - with a slight improvement in information retention capacity when both groups perform a free recall.

From a qualitative analysis perspective, at least two different situations emerge:

- Terminological problems show that even though terms were not exactly reproduced, the notions were perfectly retained even if they were described in other words; e.g. “a self-winding watch” *vs*. “winding by wearer’s arm movement” or “automatic”. This conclusion is apparent with subjects of Gr.A while they were using the concept mapping technique. Notional abstraction necessary for information accumulation operations does not seem to pose as many problems as for the recall of terms.
- Organizational problems refer to difficulties encountered in linking conceptual units. An interesting confusion during data recall was noticed for Gr.B. The analysis of *Brain* text revealed that Gr.B subjects had more problems differentiating properties of parts of the brain than subjects in Gr.A: e.g. the misattribution of one of the properties of the “brainstem” (reflex control) to the “forebrain”, or the confusion between one of “brainstem’s” parts (medulla) with another part of the “forebrain” (cerebrum). In brief, it seemed that the borderline between different notions evoked in the texts was not as distinctly clear-cut for Gr.B as it was for Gr.A subjects.

Generally speaking, recall results show that the average of recall performance was low for both groups. We attribute this performance to the time that had elapsed between text analysis exercises and to the effect of surprise; recall tests were administered 2 days later without prior notice. The low number of remembered idea units could

perhaps be attributed to the complexity of ideas described in texts used during the training sessions and during the recall tasks; text difficulty as established through the Likert scale questionnaire was significant for most subjects. This low recall value could also be explained by the fact that the twenty-hour training period, even though spread over one month, was too short to enable the subjects who were not familiar with concept mapping to develop the strategy adequately. But the traditional technique of text analysis did not produce better results either. There was, as noticed, a significant difference between the two groups' results, with a better score for Gr.A using the concept mapping technique for text analysis. The results of the Likert scales, backed by comments collected from the subjects after the recall tasks, showed that subjects were more motivated analyzing texts by using the concept representation strategy than in a discursive classical fashion.

4 Summary

From a cognitive perspective and to sum up previous observations, we would presume that high level conceptual knowledge facilitates low level text processing when it is organized in an isomorphic way through mapping between domain conceptual systems, as reflected in specialized texts, and the external representation as drawn in a map by the individual. As a result the integration and accumulation of new information in cognitive preexisting structures is facilitated. Confusion noticed in examples of Gr.B results suggests that Gr.A subjects' attention was redirected from the beginning (reading process) towards the recognition and definition of conceptual links between notions which consequently facilitated access to the mental representation.

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6 References

Ausubel, D. P. (1968). Educational Psychology. A Cognitive View. New York, Holt, Rinehart and Winston, Inc.

Baddeley, A. (1992). "Working Memory." Science 255(January): 556-559.

Britton, B. and Graesser, A. (1996). "Five Metaphors for Text Understanding." Models of Understanding Texts. B., Britton and Graesser, A. (Eds). Mahwah, NJ, Lawrence Erlbaum.

Debourges et al. (2001). "Cartographie de textes : une aide à l'utilisateur dans le cadre de la découverte de nouveaux domaines. " Actes TALN 2001, Tours.

De Groot, A.M.B (2000). "A Complex-Skill Approach to Translation and Interpreting." Tapping and Mapping the Processes of Translation and Interpreting. Outlooks of Empirical Research. S., Trikkonen-Condit and Jääskeläinen, R. (Eds). Amsterdam/Philadelphia, John Benjamins Publishing.

Ericsson, K. and Kintsch, W. (1995). "Long-Term Working Memory." Psychological Review, 102: 211-245.

Holmes, J. (1988). Translated ! : Papers on Literary Translation and Translation Studies. Amsterdam, Rod.

Jarvella, J.R. (2002). "Towards Characterizing Translator Expertise, Knowledge and Know-How: Some Findings Using TAPs and Experimental Methods." Translation Studies. Perspectives on an Emerging Discipline. A. Riccardi, (Ed.). Cambridge, Cambridge University Press.

Kintsch, W. (1998). Comprehension: A Paradigm for Cognition. New York, Cambridge University Press.

Kommers, P. A. M., Jonassen, D.H. and Mayes, J.T. (1992). Cognitive Tools for Learning. New York, Springer-Verlag.

Königs, F. (1996). "Processus mentaux étudiés chez des sujets allemands." Meta XLI, 1: 7-23.

Kremer, R. (1994). "Concept Mapping: Informal to Formal." Paper appeared in ICCS'94 - Proceedings of the International Conference on Conceptual Structures, University of Maryland.

Kremer, R. and Gaines, R. (1996). "Embedded Interactive Concept Maps in Web Documents." Paper presented at the Proceedings of WenNet'96: World Conference of The Web Society, San Francisco.

Lambiotte, et al. (1989). "Multilateral Semantic Maps." Educational Psychology Review, 1(4).

Langacker, R. W. (2001). "Discourse in Cognitive Grammar." Cognitive Linguistics, 12(2): 143-188.

Lemire, G. et al. (1998). "Aménagement de l'information, schématique et cartographie conceptuelle." Paper presented at 66e Congrès de l'ACFAS, 1998, Québec, l'Université Laval.

Lörsher, W. (1991). Translation Performance, Translation Process and Translation Strategies. Tübingen, Gunter Narr Verlang.

MacWhinney, B. (1997). "Simultaneous Interpretation and the Competition Model." Cognitive Processes in Translation and Interpreting. J.H., Danks, et al. (Eds). London. Sage Publications.

McAleese, R. (1994). "Coming to Know: The Role of the Concept Map - Mirror, Assistant, Master?" Euroconference Language, Revista Do Detua.

Meyer, B.J.F. and Poon, L. W. (2001). "Effects of Structure Strategy Training and Signaling on Recall of Text." Journal of Educational Psychology, 93(1):141-159.

Meyer, B.J.F., (1975). The organization of Prose and its Effects on Memory. Amsterdam, North Holland.

Moser-Mercer, B. et al. (2005). "Leveraging Virtual Learning Environments for Training Interpreter Trainers." Meta, L(2).

Moser-Mercer, B. et al. (2000). "Designing Studies on expertise in Conference Interpreting." Paper presented at the Conference Research Models in Translation Studies, UMIST, Manchester.

Novak, J. D. and Gowin, D.B. (1984). Learning How to Learn. Cambridge, Cambridge University Press.

O'Malley, J. and Chamot, A. (1990). Learning Strategies in Second Language Acquisition. Cambridge, Cambridge University Press.

Reader, W. R. and Hammond, N. V. (1994). "Computer-based Tools to Support Learning from hypertext: Concept Mapping Tools and Beyond." Computers and Education, 22(1/2): 99-106.

Schenk, K. D., et al. (1998). "Differences Between Novice and Expert Systems Analysts: What Do We Know and What Do We Do?" Journal of Management Information Systems, 15(1): 9-50.

Shreve, G. M. (2002). "Knowing Translation: Cognitive and Experimental Aspects of Translation Expertise from the Perspective of Expertise Studies." Translation Studies. Perspectives on an Emerging Discipline. A. Riccardi, (Ed.). Cambridge, Cambridge University Press.

Shreve, G. M. (1997). "Cognition and the Evolution of Translation Competence." Cognitive Processes in Translation and Interpreting. J.H., Danks, et al. (Eds). London, Sage Publications.

Swales, J. (1990). Genre Analysis English in Academic and Research Settings. London, Cambridge University Press.

Thomson, C. (1997). "Concept Mapping as a Means of Evaluating Primary School Technology Programs." International Journal of Technology and Design Education, 7: 97-110.

Van Dijk, T. (2001). "Specialized Discourse and Knowledge." First draft of a paper on genetic discourse and knowledge; examples in Spanish. E. M., Morato, Bentes, A.C., Cunha Lima, M. (Eds.), Homenagem a Ingedore Koch, Cadernos de Estudos Lingüísticos (Unicamp, Campinas, Brasil), 44: 21-55.

Van Dijk, T. (1997). "What is Political Discourse Analysis?" Keynote Address Congress Political Linguistics. Political linguistics. J., Blommaert and Bulcaen, C. (Eds.). Amsterdam, John Benjamins Publishing Company.

Wertsch, J. V. (1998). Mind as Action. New York, Oxford University Press.

Wilss, W. (1996). Knowledge and Skills in Translator Behavior. Amsterdam/Philadelphia, John Benjamins Publishing Company.

Wu, C-C., et al. (2004). "Using Concept Maps to Aid Analysis of Concept Presentation in High School Computer Textbooks." Education and Information Technologies, 9(2): 185-197.

Zanting, A. et al. (2003). "Using Interviews and Concept Maps to Access Mentor Teachers Practical Knowledge." Higher Education, 46: 195-214.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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THE EFFECT OF TEACHER GENERATED CONCEPT MAPS ON LEARNING OF SECONDARY SCHOOL PHYSICS

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Abstract. Physics concepts underpin much higher level technical knowledge and therefore are crucial to success in many technical disciplines. However, misconceptions in elementary physics are quite prevalent among secondary school students. Therefore, it is important to identify and implement the most effective teaching and learning methods that can reduce instances of physics misconceptions. The aim of this study was to investigate the effect of using teacher generated concept maps on the learning of linear motion concepts in the secondary schools physics. The study used a pre and post-test quasi-experimental design method with a control group. The samples were two groups of form four students from a Teluk Intan Technical Secondary School in Perak, Malaysia consisting of 28 and 29 students for the experimental and control group respectively. The experimental group was taught physics with concept maps being one of the teaching and learning tools and the control group was taught physics without concept maps. Data were gathered on types and frequency of classroom interactions, students' perception of concept maps and their learning achievements in physics test. It was found that students in the concept mapping group were more participative in class and obtained a statistically significantly higher mean gain on the physics test (μ=17.3) compared to the non-concept mapping class (μ=12.9) with $p < 0.001$. The concept mapping group also performed better on the long-term achievement measure. It was concluded that teacher generated concept maps is an effective teaching and learning tool for promoting concept learning of linear motion in physics.

1 Introduction

Having knowledge and deep understanding of physics is important especially for those who intend to pursue a career in the technical disciplines such as engineering. Unfortunately misconceptions in physic are quite common among students (Palmer, 1998). These misconceptions usually persist to interfere with students' ability to master subsequent concepts that they need to learn at higher level (Halloun & Hestenes, 1985). Remediation when the students are at higher level can be time and effort consuming not only on the part of the students but also the teacher. The time and efforts allocated for remediation could be better used for acquiring the intended objectives for that level. Therefore, more effective methods need to be identified and used in the teaching and learning of secondary school and pre-college physics.

Efforts undertaken to improve concept learning in physics include using technology supported learning system (Albacete & VanLehn, 2000); innovative teaching approach such as the interactive conceptual instruction approach (Savinainen & Scott, 2002) and cognitive tools such as concept maps (Zieneddine & Abd-El-Khalick, 2001). Among the approaches mentioned here, concept mappings have been widely reported for purportedly giving good results in developing understanding of concepts in general. A concept map is a graphical based method that shows the relationships between the main concept and several others sub-concepts (Novak & Gowin, 1984). Its basic principle is 'the use of simple comprehensive texts containing facts, definitions and principles'. A concept map is said to be able to clarify the relationships between the various elements within a concept (Deshler, 1990). Some literature indicated that the act of drawing the map itself forces the person who draws it to confront his pre-conceived ideas and understanding of a concept and to seek clarifications where necessary (Inman, Ditson & Ditson, 1998; Ellis, Al Rudnitsky & Silverstein, 2004).

Other reported benefits of concept maps to teaching and learning in general include, increase effectiveness of teacher-students communication (Kinchin, 2003; Kinchin & Alias, 2005), improved efficiency in notes-taking (Srantesson, 1991) supports collaborative learning efforts (Belbin, 1981 & Stäuble, 2005) and aids in memorization and recall (Deschler, 1990). Specific to learning in physics, results of better learning through concept maps have been reported by Pankratius, (1990); Normah & Tamby Subahan (1997) among others. Most of these studies however, were looking at the effect of student-generated concept maps on learning. The effect of teacher generated concept maps has been less studied. Knowing the extent to which teacher generated concept map can influence learning is important because teacher generated maps is easily implemented and therefore can be of academic significance and practical significance.

1.1 Purpose of study

The main purpose of the study was to determine the effects (short-term and long-term) of teacher generated concept maps on students' understanding of physics concepts. In order to have a better understanding of how using concept maps may affect learning, it was also important to look at both the product (learning gain) and the process of learning itself, i.e., looking at what happens in the classrooms during the teaching and learning process. Therefore, it was also the aim of this study to look at how using concept maps affect classroom interactions. Since, perceiving something in a certain light has been known to affect a person's response to the object perceived; knowing students' perception towards the use of concept maps was also thought to be relevant for a better understanding of the effect of concept mapping technique on students' achievements. Four research questions were formulated for the study. The research questions are:-

(i) Is there a difference in the short-term learning gain between the group that does and the group that does not use concept maps?
(ii) Is there a difference in the long-term learning gain between the group that does and the group that does not use concept maps?
(iii) What are students' perceptions of the usefulness of concept maps in teaching and learning?
(iv) Is there a difference in the frequency and type of classroom interactions between the group that does and the group that does not use concept maps?

The scope of the study is limited to the effect of concept maps on the learning of six inter-related concepts in linear motion taught in form four physics namely, speed, distance, velocity, displacement, acceleration and deceleration. Only manually constructed concept maps in Bahasa Melayu were used in the study.

2 Research Methods

To answer the first and second research questions, the quasi-experimental design method of pre and post test with a control group was used. The research design is shown in Figure 1. The independent variable is "using or not using concept map" and the dependent variable was score on the physics achievement test. The participants for the study were two intact classes of form four mechanical engineering studies students from Teluk Intan Technical Secondary School located in Perak, Malaysia. The topic chosen was linear motion which is one of the earlier topics taught in form four physics. Mastering the concepts within this topic is important as they form the basis for learning of more advanced topics later on.

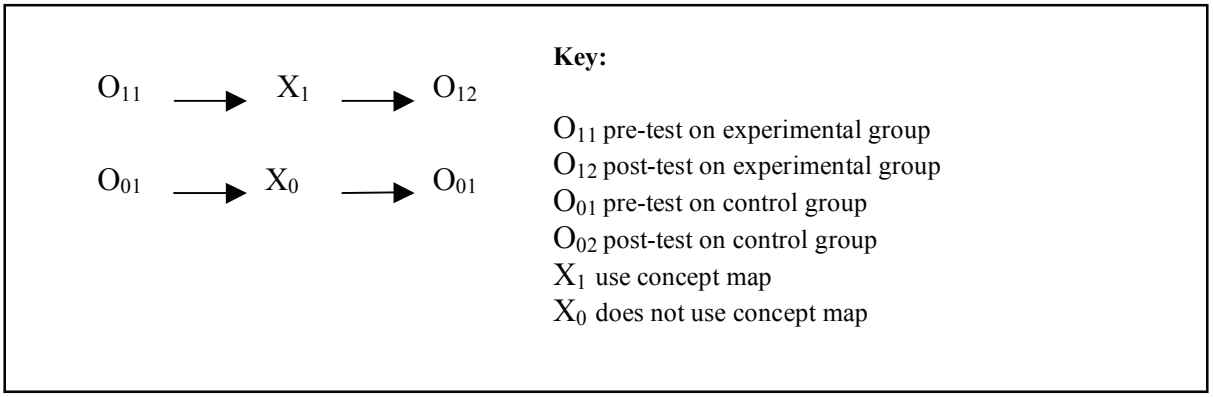


Figure 1: Research design for the study

Three data gathering instruments were used, (i) a physics achievement test, (ii) an observation schedule and (ii) a questionnaire. The achievement test consisted of 20 items to be answered in forty minutes. The objective was to measure knowledge on concepts of speed, velocity, displacements, distance, acceleration and deceleration. Two response formats were used i.e., choosing from given alternatives and free response style. Content validity was achieved through subject matter expert's verifications based on the expert opinion of an experienced physics teacher in the school. The reliability estimate based on the Cronbach alpha method was 0.58. The estimated reliability was

acceptable in accordance with Rudner & Schafer (2001), two measurement experts who state that a teacher developed classroom test with a reliability estimate of 0.5-0.6 is acceptable. Therefore, the test instrument used in this study was considered to be adequately reliable for the purpose of this study.

The perception questionnaire was used to gather data on students' perception of the usefulness of concept maps to teaching and learning. It consisted of 14 items that requires the participants to give a rating of their agreements to a given statements on a scale of 1 (strongly disagree) to 5 (strongly agree). The reliability estimate based on the Cronbach alpha method is 0.84, which is consistent with reliability estimates of perception questionnaires from other such studies (Quek, Wong & Fraser, 2002) who obtained reliability estimates ranging from 0.5-0.9.

The observation schedule was used to gather data on class interactions. The schedule is divided into sections. Each section represents a 10 minutes session of class teaching. Observations were recorded for any actions by students that indicate interactions or non-interactions such as asking questions voluntarily, responding voluntarily, interacting with friends, writing down notes, giving opinions freely and sleeping in class. An assistant was trained to help with the gathering of the observation data. A video camera was also used to record events during the teaching and learning process.

2.1 Procedures

Pre-test on physics were given to both groups prior to the intervention. During the intervention, the experimental group was taught the chosen physics concepts using concept maps as a teaching and learning tool while the control group was taught the same concepts without concept maps. In other words, the main difference between the learning experiences of the two groups was in the use of concept maps by teacher and students in the experimental group. A concept map was drawn progressively by the teacher in line with the progress of the lesson. At the end of the lesson, an overview of the main concept and its sub-concepts including their propositional links as shown in Figure 2 was produced. Translation of the concept map is given in the Appendix.

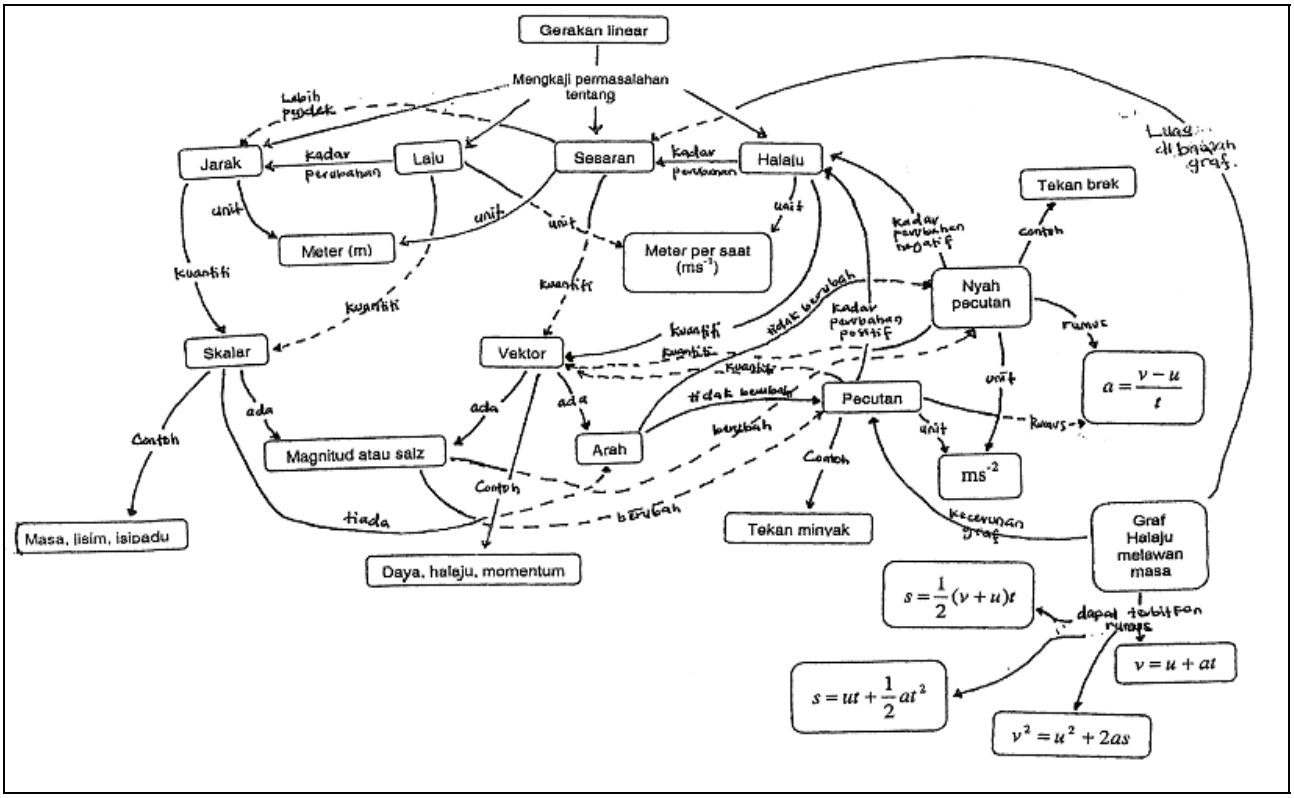


Figure 2: Teacher generated concept map in Bahasa Melayu (Malay Language)

Both groups were taught by one teacher, therefore, teacher differences was not a source of confounding. Both groups also received a set of identical brief notes prepared in power-point presentations style. Both groups were given post –test after the class. Table 1 illustrates a typical unit of teaching and learning activity.

Table 1: Typical unit of teaching and learning activity

Concept map group	**Non-concept map group**
• Teacher explains, • Teacher draw map, • Students copy map • Students encouraged to ask, • Students encouraged to expand on the concepts by giving examples • Students asked to explain using the concept map	• Teacher explains, • Teacher write notes • Students copy notes • Students encouraged to ask, • Students encouraged to give examples to elaborate points • Students asked to explain

3 Results and discussions

Before presenting the results per-se, a check on group equivalence based on the pre-test scores will be shown first to be followed by the results on learning gains, perception towards concept maps and classroom interactions. The mean scores μ on the pre-test were very similar for the two groups as shown by the descriptive statistics in Table 2. Having confirmed equal groups' variances (Levine's test with $p>.05$), comparison between the mean scores was carried out using an equal variance *t*-test. The *t*-test results showed that the difference was not statistically significant (Table 2). Therefore, the two groups were assumed to be equivalent with respect to their initial knowledge and understanding of linear motion concepts.

Table 2: Descriptive statistics and *t*-test results on initial group differences

	Descriptive statistics		Levine's Test		Independent *t*-test		
Group	μ	*s*	*F*	*p*	*t*	*df*	*p*
Experiment	9.75	3.18	0.14	0.905	-0.093	55	0.926**
Control	9.83	3.10					

**Difference is not statistically significant, $p>.05$

3.1 Learning gains

Two types of learning gain were investigated, immediate and long-term. Table 3 shows the descriptive statistics and the *t*-test results on difference in learning gains. The data were obtained immediately after the intervention and therefore this is considered as the immediate learning gain. The immediate mean gain score (μ) for the experimental group (μ=7.53) is twice as much as the control group (μ=3.03) and the difference is statistically significant at the 5% level of significance (p=0.000) based on an equal variance independent *t*-test. The equal variance independent *t*-test was used after ascertaining that the two groups have similar variances as indicated by the *p*-value for the Levine's test that is greater than 0.05. The statistically significant difference in the *t*-test result means that the experimental group obtained larger learning gain compared to the control group suggesting the benefit of teacher generated concept maps on learning.

Table 3: Descriptive statistics and *t*-test results for difference in learning gains

	Descriptive statistics		Levine's test		Independent *t*-test		
Group	*μ*	*s*	*F*	*p*	*t*	*df*	*p*
Experiment	7.53	3.12	0.75	0.39	5.31	55	0.000*
Control	3.03	3.32					

*Difference is statistically significant, $p<.05$

The effect size of the difference based on Bloom (1984) was computed as 1.1. According to Willingham, (2002), an effect size of as low as 0.25 can be considered practically significant and above 1.0 is considered exceptional in education research. Clearly, the gain in learning by the experimental group is not only statistically significant but most importantly it was academically and practically significant indeed.

Table 4 shows the means for long-term gain measured six weeks after the pre-test. The control group experienced only a small drop while the experimental group experiences a big drop in long-term gain. Nevertheless, the mean in long-term gain of the experimental group is still larger than the mean of the control group. An equal variance *t*-test indicated that the difference was statistically significant at the 5% level of significance.

Table 4: Descriptive statistics and *t*-test result for difference in long-term learning gain

	Descriptive statistics		Levine's test		Independent *t*-test		
Group	μ	*s*	*F*	*p*	*t*	*df*	*p*
Experiment	4.39	3.201	1.790	0.186	2.08	55	0.042*
Control	2.34	3.143					

*Difference is statistically significant, $p<.05$

Effect size obtained for the difference was 0.65 which is comparable to a study on long-term gain by Rohrer, *et al.* (2005) who obtained an effect size of 0.75 in a study on the impact of over learning. Again, the gain is practically significant in accordance with Willingham (2002) and therefore, it appears that the impact of concept map on long term learning is also commendable. All data analysis results were based on SPSS version 13.

3.2 Perception towards the usefulness of concept maps

Overall rating by students on the usefulness of concept maps was high, ($\mu = 4.27$) indicating that students perceive concept maps as a useful tool to their learning. The highest rating was for the item that measures the usefulness of concept map in promoting understanding ($\mu= 4.57$) which is consistent with the benefit of using concept maps as proposed by Novak & Gowin, (1984). The lowest rating is for the two items that asses students' tendency to use concept maps in discussion with teachers which is 3.75. The result here appears to be in contradiction to previous findings that support the positive role of concept maps in promoting discussion (Kinchin, 2003 and Kinchin & Alias, 2005). However, in the case of Kinchin and Alias (2005) the maps were students' generated and the questions were from the teacher who was trying to reduce misconceptions in the students. On the other hand, the maps in the current study were teacher generated and therefore most probably very clear to the students and therefore did not require many discussions. Further investigation is required in order to understand the real underlying causes of the lower rating for these particular items.

3.3 Class interactions

Figure 3 illustrates the type of interactions and frequency observed during a 40 minutes lesson on linear motion. From the graph, it can be seen that there are differences between the two groups. For example, the number of students taking down notes in the experimental group is consistent from the first 10 minutes to the fourth while the number in the control group decreases from 29 down to 5 at the end of the 40 minutes lesson. In fact, all types of interactions are decreasing for the control group except for two, *interactions with friends* and *the number of students who sleep*. The increase in interactions with friends together with the drop in the number of students taking down notes (negative interactions) is taken to be a strong indicator of boredom setting in for the control group which is further confirmed by some students in the group falling asleep (even if only two of them). The higher incidences of positive classroom interactions for the concept map group were interpreted as the positive impact of concept maps on the learning process.

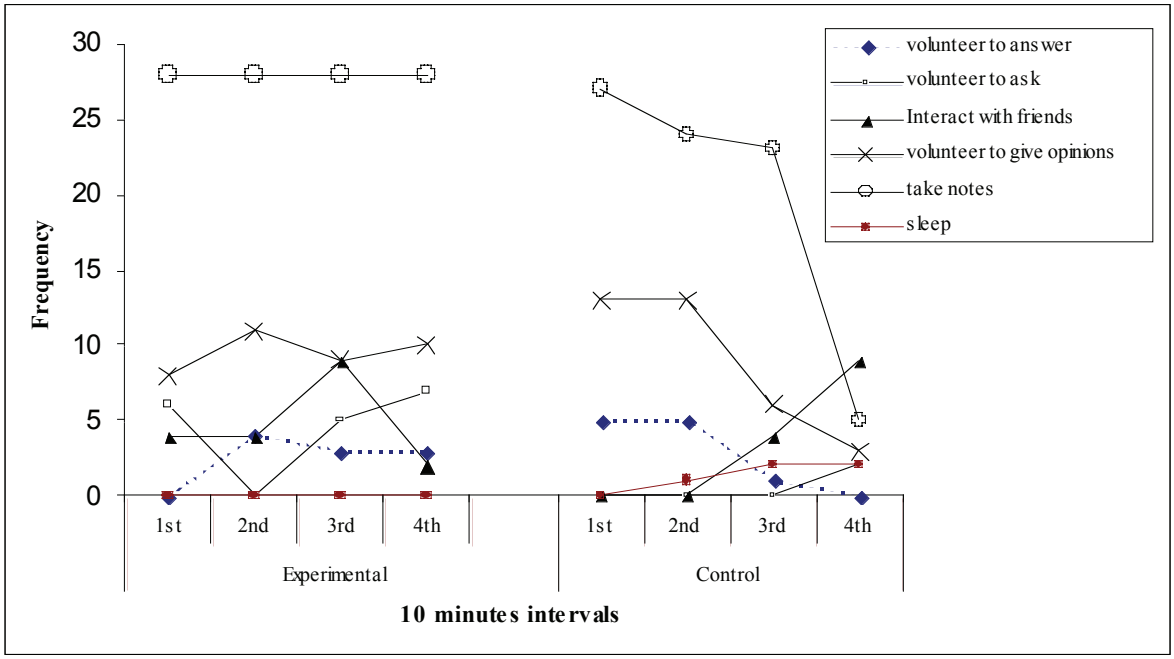


Figure 3: Distributions of class interactions

4 Conclusion

This study sets out to determine whether teacher generated concept maps benefit students in the learning of linear motion concepts in secondary school physics. The findings indicate that students do learn better when concept maps are used in the teaching and learning of the concepts and students do retain more of what they have learnt in the long-term. The positive impact of teacher generated concept maps on both short-term and long-term learning was not only statistically significant but also academically significant. Therefore, serious considerations should be given to the adoption of concept maps as a teaching and learning tool in the learning of physics even at the level of only the teacher drawing the concept maps. The findings from the study also indicate that the use of concept maps promotes students-teacher and student-student interactions supporting active learning which is conducive to learning in general which is a factor contributing to the higher gain in learning. Students' positive perception towards concept maps in the current study could also be a factor explaining the positive impact on learning. It is not known however, if the same effect on learning will be found where students taught using concept maps have negative perceptions of concept maps. Therefore, future study could be carried out to determine if perceptions of concept maps have any bearing on classroom interactions and learning gain. The current findings were limited to teacher generated concept maps. The impact of students generated concept maps on learning gain may not be the same because students' attributes such as concept mapping skills and learning preferences may interact with learning. Studying the interactions between students' skills and preferences towards concept mapping may be the focus of future study.

5 References

Albacete, P. L. & VanLehn, K. A. (2000). Evaluating the effectiveness of a cognitive tutor for fundamental physics concepts. In L. R. Gleitman & A. K. Joshi (Eds.), *Proceedings of the 22nd. Annual Conference of the Cognitive Science Society,* 25-30. Mahwah, NJ: Erlbaum

Belbin, R. (1981). *Management Teams*. Oxford:Heinemann.

Bloom, B. S. (1984). The 2 sigma problem: the search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*, 4-16.

Deshler, D (1990). *Conceptual Mapping: Drawing charts of the mind in fostering critical reflection in Adulthood*. Eds. J. Mezirow, 336-353. San Francisco: Jessey-Bass.

Ellis, G. W., Al Rudnitsky & Silverstein B. (2004). Using conceptual maps to enhance understanding in engineering education. *International Journal of Engineering Education,* 20*(6)*. Online: http://www.smith.edu/engineep/papers/concept_maps.pdf

Halloun, I. A. & Hestenes, D. 1984. Common sense concepts about motion. *American journal of Physic, 53*(11), 1056-1065

Inman, L. A., Ditson, L. A. & Ditson M. T. (1998). Computer-based concept mapping: promoting meaningful learning in science for students with disabilities. *Information Technology and Disabilities* [Online serial], 5(1–2). Available: http//www.rit.edu/~easi/itd/itdv05n1-2/article2.html

Kinchin, I. M. (2003) Effective teacher student dialogue: a model from biological education. *Journal of Biological Education, 37*(3), 110-113.

Kinchin, I. M. & Alias, M. (2005) Exploiting variations in concept map morphology as a lesson-planning tool for trainee teachers in higher education. *Journal of In-service Education. 31(3),*569-591.

Normah Abd. Aziz & Tamby Subahan Mohd. Meerah. (1997). Salah konsep dalam kinematik di kalangan pelajar tingkatan 4: Penggunaan peta konsep. *Jurnal Pendidikan, 22*, 51-68.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to Learn*. New York:Cambrige university Press.

Palmer D. H. (1998). Measuring contextual error in the diagnosis of alternative conceptions in science. *Issues in Educational Research, 8*(1), 65-76.

Pankratius, W. J. (1990). Building an organized knowledge-base: Concept mapping and achievement in secondary school physics. *Journal of Research in Science Teaching*, *27*(4),315–333.

Puntambekar, S., Stylianou, A. & Hübscher, R. (2003). Improving navigation and learning in hypertext environments with navigable concept maps. *Human-Computer Interaction*, *18*(4), 395-428.

Quek C. L., Wong, A. F. L. & Fraser, B. J. (2002). Gender differences in the perceptions of chemistry laboratory classroom environments. *Queensland Journal of Educational Research*, *18*(2),164-182. http://education.curtin.edu.au/iier/qjer/qjer18/quek.html

Rohrer, D., Taylor, K.,. Pashler, H, Wixted, J. T. & Cepeda, N. J. (2005). The effect of overlearning on long-term retention. *Applied Cognitive Psychology, 1,* 361–374. Published online 17 December 2004 in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/acp.1083

Rudner, L. M. & Schafer, W. D. (2001). Reliability. *ERIC Digest*. Online http://www.ericdigests.org/2002-2/reliability.htm

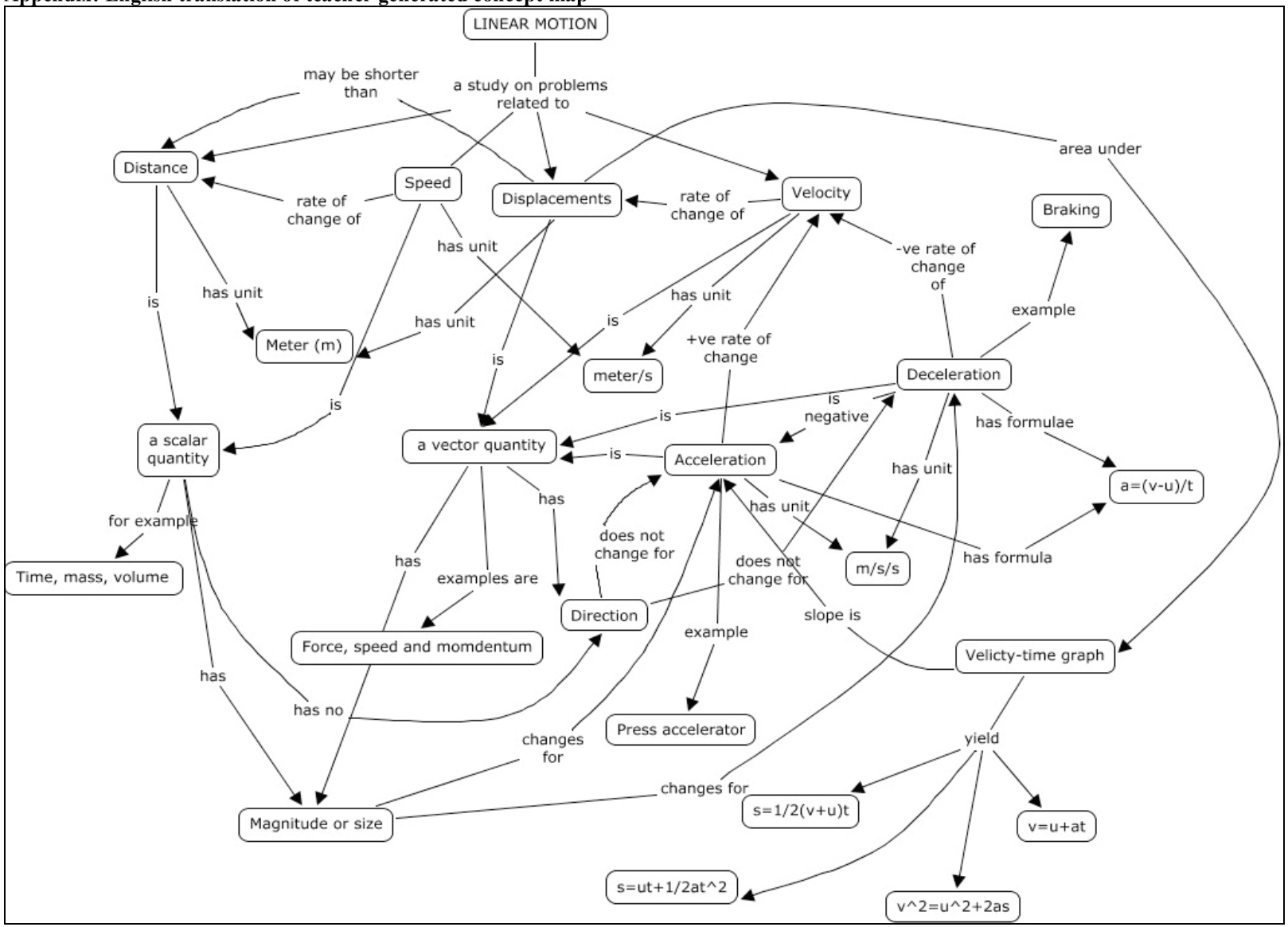
Srantesson, I. (1998). *Learning Maps And Memory Skill*. 2nd Edition. United Kingdom:Kogan Page

Stäuble, B. (2005). Using concept maps to develop lifelong learning skills: A case study. *In The Reflective Practitioner*. Proceedings of the 14th Annual Teaching Learning Forum, 3-4 February 2005. Perth: Murdoch University. http://lsn.curtin.edu.au/tlf/tlf2005/refereed/stauble.html

Willingham, D. T. (2002). Allocating student study time "massed" versus "distributed" practice. *American Educator*. Online http://www.aft.org/pubs-reports/american_educator/summer2002/askcognitivescientist.html

Zieneddine, A. & Abd-El-Khalick, F. (2001). Doing the right thing versus doing the right thing right: Concept mapping in a freshmen physics laboratory. *European Journal of Physics, 22*, 501-511.

Appendix: English translation of teacher generated concept map



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THE USE OF CONCEPT MAPPING TO DETECT THE EVOLUTION OF KNOWLEDGE ABOUT JEWISH HISTORY

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Abstract. In this paper we describe the identification and characterization of changes within an individual adolescent's knowledge of Jewish history after exposure to an instructional intervention in this area. The data consisted of three concept maps, that were constructed before, immediately after the intervention, and two and a half months later. These concept maps were derived by the SConSAT version of concept mapping that does not restrict in any way the arrangement of the concepts. Therefore the constructed concept maps can be non-hierarchical and may contain new elements, namely, concept clusters and multi-concept links. The comparative analysis of these maps showed that a major change occurred in the student's knowledge immediately at the end of the course, that this knowledge structure remained highly stable over a long period when there was no history teaching. Yet the latter knowledge structure more accurately represents the content and style of the course of instruction than does the immediate post-intervention knowledge structure. The findings are discussed from three perspectives. Philosophically, they are relevant to claims about a prevailing and general antipathy between history and memory. Psychologically, they illustrate the stability of knowledge structures. Methodologically, they reveal the potential of a concept mapping methodology to generate grounded theory about change in historical knowledge.

1 Introduction

History is widely conceived as the study of the past by professional historians who base their conclusions on both written documents and oral reports. Historiography, the cultural product of historians, draws attention to and challenges societal memory as reflected in tradition (Yerushalmi, 1989). In many societies, historians introduce debate over historical truth and traditional memory into the curriculum, provoking questions concerning the teaching and learning of history (Nora, 1989). For Jewish educators, such questions include: what is the experience of Jewish 'non-expert' students when they encounter Jewish historiography over a period of time? Do students experience a developing rupture between their memories of the Jewish past and the past described by historians? Does the critical study of history undermine the authority of Jewish tradition and collective memory or does it encourage students into greater identification with the community's past and future - in accordance with the explicit aspirations of a number of Jewish day schools?

There have been a few unsuccessful attempts to examine whether philosophical conclusions about a dissonance between history and memory correspond to a psychological reality and the ways in which children think about historical evidence in general (Shemilt, 1974, Dickinson and Lee, 1984). These studies combine Piagetian psychology and Hirstian philosophy in a manner that is unsuited to the examination of the relationship between historiography and other more traditional means of apprehending the past (e.g., Herbst, 1985). Therefore, our main purpose in this paper is to identify and characterize changes within an individual adolescent's propositional knowledge of Jewish history short and longer times after exposure to instructional intervention in this area.

2 Method

2.1 Participant and settings

The participant in this case study, Michael, was a member of a group of Jewish 18 year old students from England. He was selected for case-study since his case vividly displays features shared by other members in the sample. The study had 4 phases: pre-intervention concept mapping individual interviews, a period of instruction, post-intervention mapping interviews within a week of the end of instruction, and final delayed post-intervention mapping interviews two and a half months later.

The instruction consisted of five, one hour long, units which were collectively titled "Reactions to the Destruction of the Second Temple". Instruction was shaped so that (a) students could see how traditional Jewish texts can also be treated from a critical and historical perspective, (b) events in Jewish history with which students were already familiar would be explained without recourse to theological categories, and (c) students would

encounter a comprehensive historiographical explanation for developments in Jewish history which replaced the assumptions of memorial Jewish history with a rival set of assumptions taken from the social sciences.

2.2 The instrument

The instrument was the cognitive mapping interview,which is a Standardized modified version of Champagne and Klopfer's (1981) ConSAT. In this individual interview an individual constructs a cognitive map from a predetermined list of concepts that span a knowledge domain (Hoz, Bowman and Chacham, 1997). The cognitive mapping has three exclusive distinctive features in comparison to the Novakian concept mapping: 1. The link labels are full sentences which are meaningful to the interviewee, and may consist of several propositions that express rich ideas (whereas in other versions these are one or two-word links which express simplistic propositions, e.g., Stuart, 1985, Herl et al., 1996). 2. Any organization of the given concept is admissible, in particular spatial non-hierarchical arrangements (whereas other versions require and impose hierarchical organisation, e.g., Novak and Gowin, 1984), and 3. the cognitive map may include the following elements: a. concept-clusters (encircled, and may include embedded sub-clusters), b. various type of links between any kind of element (designated by large black dots), such as links among 3 or more concepts, a concept and a concept cluster, or two concept clusters (whereas other versions include only bi-concept links and and no concept clusters).

2.3 Concept Selection

The selection of concepts for the SConSAT interview is contingent on the purposes of the research and determines to a large extent the nature of obtained knowledge representations (Hoz, Tomer and Tamir, 1990). We selected 13 concepts in order to satisfy various content and anlysis-related criteria (in Pomson and Hoz, 1998): G-D (spelled in a traditional manner so as not to offend any of the interviewees), JUDAISM, LAND OF ISRAEL, JEWISH PEOPLE, TEMPLE, WAR, RABBIS, ROMANS, DESTRUCTION, SURRENDER, ADAPTATION, DEFIANCE and HISTORIANS.

2.4 The Analysis

We considered structural and content characteristics separately and conjointly. The former characteristics are more conspicuous, and pertain to the chunking of concepts and the formation of clusters and subclusters, the density of concept clusters, the mutual relations among concept clusters, the existence of central concepts, the linear/sequential or other arrangement of clusters and the whole knowledge structure, the bridging of clusters by individual concepts, and the numerousity of clusters. The latter characteristics are less conspicuous being pertinent to domain-specific ideas. Based on these facets, data have yielded the following 4 dimensions:

2.4.1 Title of Map

This serves as a useful indicator of what maps as a whole represent, since it forces interviewees to articulate conceptions whose content is more meaningful than merely taking a sum of the propositional parts of a map. Additionally, we determine what the relationship is between the map title and the content and organisation of the map.

2.4.2 Cardinal Concept

This is a concept on which the rest of the map hinges, or around which it revolves. This may be a central or focal concept (as in e.g., Hoz et al., 1997) but not necessarily, and its identification cannot be attained in only quantitative or structural terms.

2.4.3 Representation of Commonplace Jewish Concepts

The way the concepts G-D, JEWISH PEOPLE, JUDAISM and LAND OF ISRAEL are represented can provide the clearest indication of the view of Jewish history which shapes different cognitive structures. In structural terms these concepts can either form a cluster or a distinguished part of knowledge, or be dispersed throughout the map like other concepts. In semantic terms, these concepts can be construed in a way which is symptomatic of a particular theory of Jewish history.

2.4.4 Main ideas and their representation through form and content

Here we intend to examine cognitive structure not only according to a limited number of structural and a slightly greater number of grammatical criteria, but according to both the semantic and structural content of propositional networks. We have paid attention to the way in which propositional networks may be powerfully shaped by a guiding metaphor or idea (Wilson, Shulman and Richert 1987). Any form of subject matter which has been mastered by anyone will have been submitted to some major idea or master story and this may emerge (explicitly or implicitly) during the representation of knowledge structure, although we recognise that there is always a danger of reading too much into a map.

3 Results and Discussion

Michael's concept maps are presented in Figures 1-3, where the following conventions are used: 1. The sentence written on the connecting lines is the student's relation between (or among) the linked concepts; 2. Arrows show the direction of a relation; 3. Concept clusters that were formed by the student are encircled and their titles (written on their circumference) express the student's rationale for clustering these concepts; 3. Dark points signify relations among multiple concepts, between a concept and a concept-cluster, or between a concept-cluster and another concept cluster; 4. Boxed concepts were those which the interviewee added to the List concepts.

3.1 Michael's historical knowledge.

3.1.1 Pre-intervention

Michael's knowledge structure cannot at this stage be characterised as paradigmatically historical, memorial or sociological since too many of its features point in differing directions (Pomson and Hoz, 1998). However, there are a number of ways in which Michael's historical knowledge does display an orientation which could be regarded as theological rather than mundane. 1. The cardinal concept JEWISH PEOPLE has been grouped together with the other commonplace concepts (JUDAISM, LAND OF ISRAEL and G-D) under the sub-title "Judaism". 2. The map's overall title, "Judaism and Challenges to it" reflects a greater interest in the Jewish religion or theological questions than in the Jewish people. 3. The concepts that Michael added, TORAH and ADVANCEMENT, have not been integrated into the network. This may be interpreted as pointing to a tension that, despite the consistency within the propositional knowledge, there is a sense that it is only a partial elaboration of a larger and more complete structure which has not been fully revealed.

Michael's historical knowledge is predominantly represented in memorial rather than critical terms since it lacks a central distinction between the past and those who reconstruct it in the present, which is an essential predicate of a critical-historiographical orientation (Plumb, 1969). Michael seems to conceive of himself as part of the history he presents and he appears to conceive of the past as continuing to live in the present.

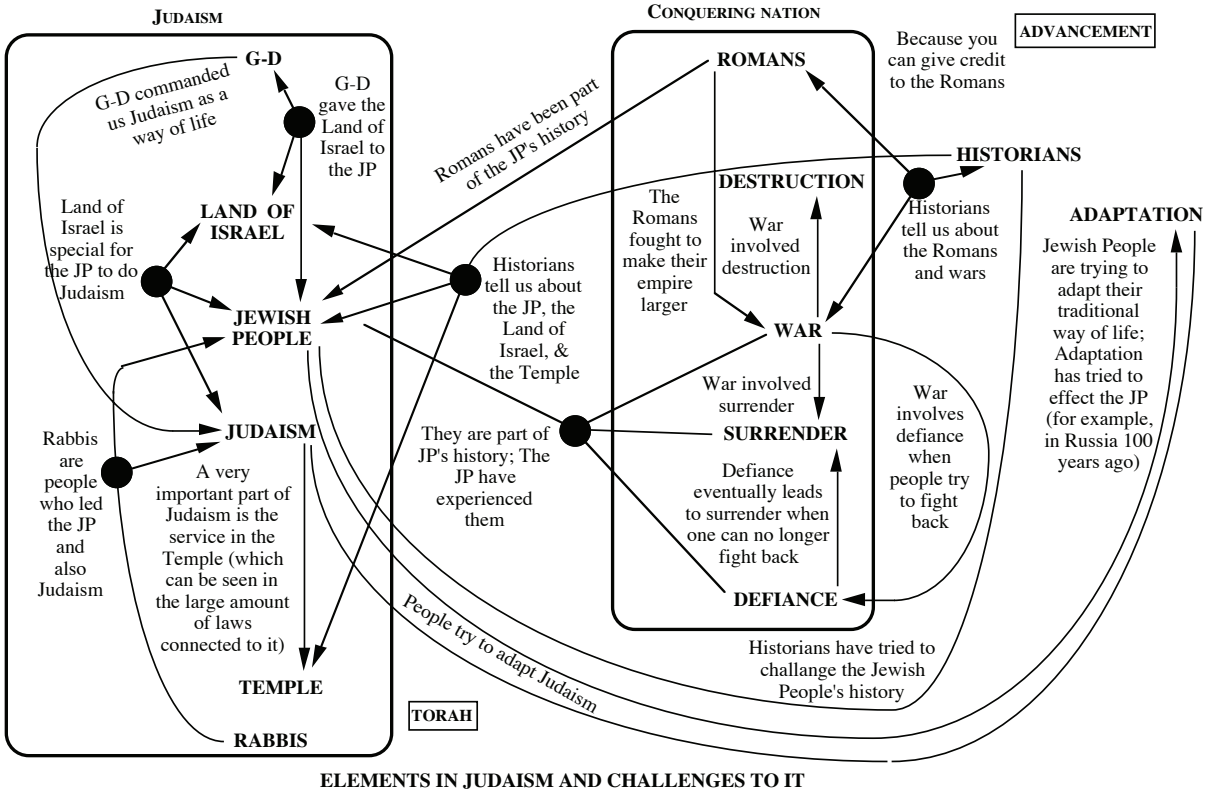


Figure 1. Michael's pre-course historical knowledge structure.

3.1.2 Immediate post-intervention

Michael's post-intervention knowledge is focused explicitly and unambiguously on the contents of a discrete and temporally-limited period of history, described by the main title "The Conquest of Israel by the Romans", whereas his pre-intervention map expresses sprawling or timeless concerns. In structural terms, the structure is apparently complete, it is limited only to include content conceived as explicitly relating to this particular historical episode; it contains a smaller and less diffuse number of links with little elaboration, and no supplementary concepts have been added either, as it would seem that Michael no longer needs additional concepts in order to bring out their proper meaning. In semantic terms, the commonplace Jewish concepts have become subordinate to the map's external and historically limited concern – "the ROMANS - which now seems to be the map's cardinal concept, initiating the map's propositional flow, and being a referent for its overall title. Jewish commonplace concepts have been labelled "Enemies of the Romans" and no longer exist as a self-contained set with an intrinsic meaning of their own. In fact, the concept G-D does not directly inform the meaning of the other three commonplace Jewish concepts, and the collective meaning that these concepts possess derives almost entirely from their relationship to the Romans.

Michael's post-intervention knowledge is concerned neither with theology in general nor Judaism in particular, but with a particular episode in the past "related to us" by HISTORIANS. This is evident by the historians' standing outside the substance of the map, in a secondary relationship to the rest of its concepts. As Michael expresses it, they were "not involved *at that time*" (emphasis added) and are only people who tell us about what happened, afterwards. This is certainly different from the pre-intervention knowledge where the blurring of past and present was typified by the way in which HISTORIANS was conceived as both being part of the challenge to JUDAISM and also as the mediating agency through which we know about such a challenge.

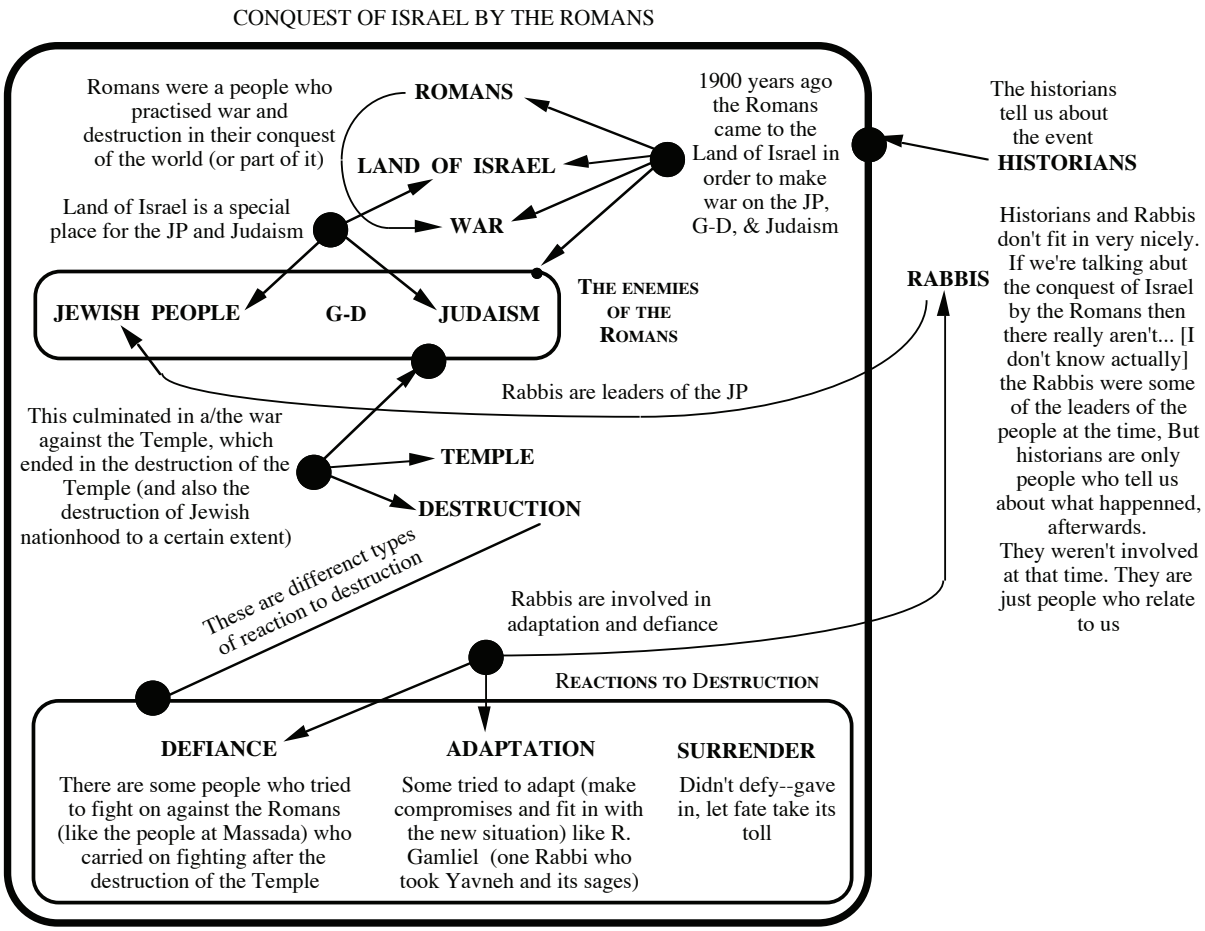


Figure 2. Michael's immediate post-course historical knowledge structure.

Additionally, Michael's knowledge is remarkably faithful to the substance of the course as conceived and presented by the course teacher. Thus, the role of the organizing concepts (DEFIANCE, SURRENDER and ADAPTATION) is generally faithful to their role in the course of instruction. Michael has accurately articulated a major principle within the course which represented these concepts as making sense of reactions to destruction in any number of Jewish or non-Jewish contexts, as he generalizes "there are different reactions to DESTRUCTION". His representation also reflects the way in which, during the course, these concepts were applied to a particular historical instance. Thus, when he provides a detailed representation of these three organising concepts, each is informed by historical particulars derived from the course, which, again, correctly reproduce the specific historical content given to them during instruction.

3.1.3 Delayed post-intervention

Michael's delayed post-intervention knowledge bears a striking structural similarity to his immediate post-intervention knowledge. Yet, there have occurred three subtle changes that have faintly restored a Jewish emphasis to the knowledge structure, which now represents an episode in Jewish history, rather than an historical episode which affected the Jewish people.

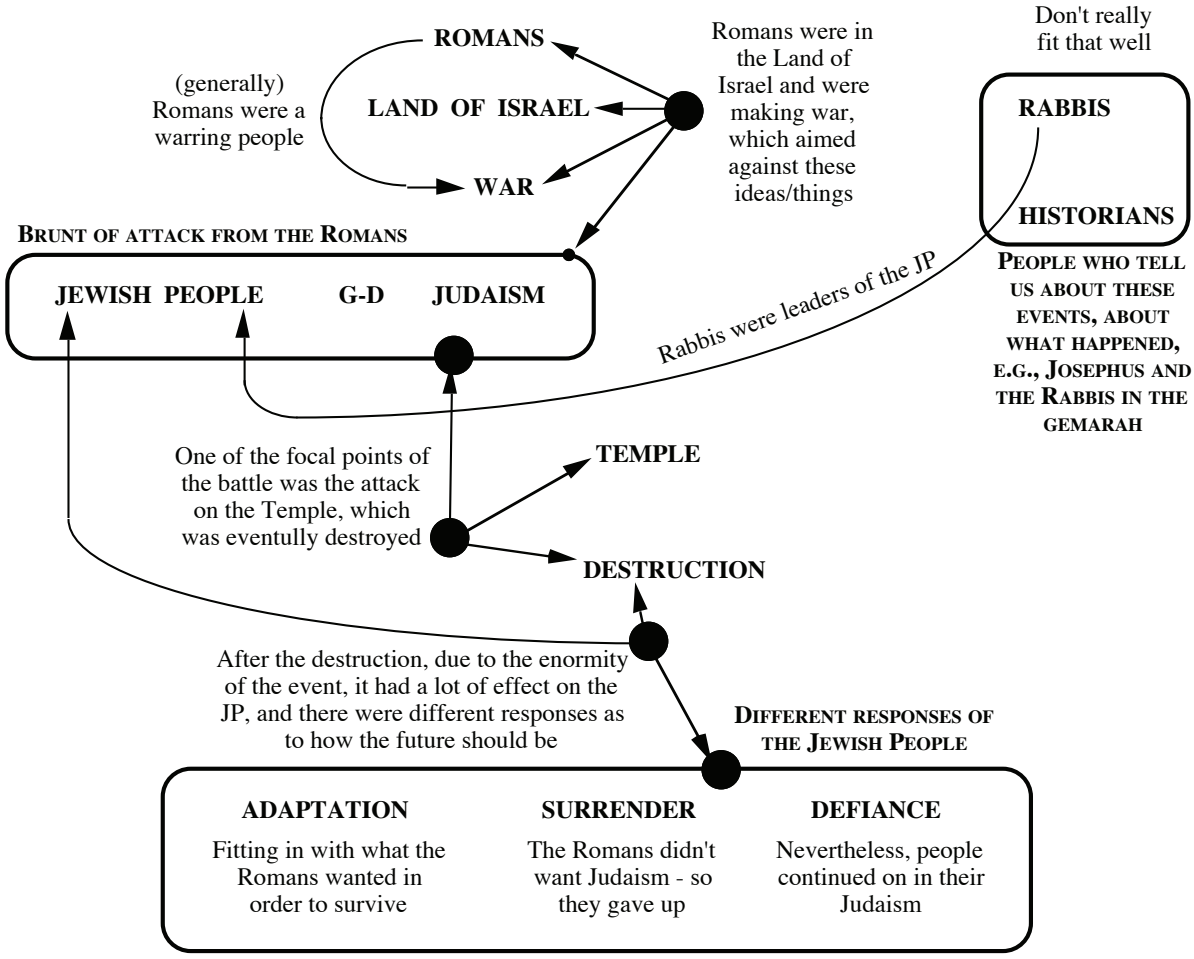


Figure 3. Michael's delayed post-course historical knowledge structure.

The title of the delayed post-intervention map is paradoxically a more faithful reflection of the course's content than the title of the immediate post-intervention map, which had been "Conquest of Israel by the Romans." This also suggests that overall the map's main concern is with the events of Jewish history, rather than with events in Roman history which in the immediate post-intervention representation happened to relate to Rome's enemies in the Land of Israel. The organizing concepts (SURRENDER, ADAPTATION and DEFIANCE) are now collectively labelled as "Different responses of the Jewish People", rather than as in the immediate post-intervention as "Reactions to destruction." This new sub-title confers an explicit Jewish point of reference on these concepts which was absent in the immediate post-intervention, where the sub-title's reference was so general it did not even relate to specifically Jewish phenomena. The commonplace Jewish concepts are now labelled ("Brunt of the attack from the Romans") somewhat equivalent to the label they received in the immediate post-intervention map ("The enemies of the Romans"), but signifying a slight promotion in the valuation of these concepts, in that they may now be regarded as significant victims rather than mere opponents of the Romans. Thus, the delayed post-intervention knowledge structure seems a more accurate representation of the content of the course of instruction (intervention) than was the immediate post-intervention conception.

In conclusion, taking the three knowledge representations together, it becomes evident that the ideas which were presented in the intervention course have become a greater part of Michael's knowledge only after considerable time had passed, even though he received no further formal instruction.

4 Generalisations and implications

In the first place, Michael's conceptions display a strongly increasing acquisition of focus. And yet, as we have already noted, paradoxically and contrary to layperson expectation, it is Michael's delayed post-intervention map which is probably more faithful to the style and substance of the pedagogic intervention than was the immediate post-intervention map. Indeed, while, overall, Michael displayed an impressive facility in rearticulating the contents of the course, he did so with greater precision two and a half months after the intervention, in the delayed post-intervention, than in the immediate post-intervention which took place within days of the end of the course. This could be because it took time for him to crystallise the new conception, in that schema change takes time, or because after producing one representation, he had to struggle with the metacognitive challenge posed by having to process a new entity.

We contend that this seemingly paradoxical phenomenon should be considered in association with another striking feature of this case. As already noted, apart from with respect to some subtle and semantic differences, Michael's immediate and delayed post-intervention representations display a remarkably strong similarity to each other. This similarity suggests that cognitive maps should not in general be regarded as either arbitrary or casual. A similar stability regarding teachers' conceptions about writing instruction, over one year, in the absence of intervention or treatment, was reported by Hoz and Zellermayer (1995). This is further evidence for the edumetric aspect of the construct validity of the SConSAT version of concept mapping, namely, that it reflects real changes and shows none in the absence of any real change, except for random fluctuations (Carver, 1974; Hoz et al., 1997).

Several conclusions can be drawn from Michael's conceptional change, which can be generalised, as by its very nature this instance was selected for case study because it was strongly representative of the larger sample.

1. Adolescents' conception of Jewish history can change in substantial, stable and potentially important ways under the influence of shortish periods of instruction.

2. Critical conceptions of Jewish history can place memorial representations under some strain, by emptying them of their theistic content, by drawing a clearer distinction between the past and present, and by eroding their personal significance.

3. Changes in the representation of Jewish historical knowledge following an encounter between memorial and critical conceptions of Jewish history appear to correspond to Piaget's (1971) notions of assimilation and accommodation: Piaget influentially depicted biological adaptation as involving processes of assimilation, these being efforts to deal with the environment by making it fit into the organisms own existing structures, and processes of accommodation, being efforts to fit the behaviour of the organism to the environment.

Taken together, these conclusions exhibit a certain ambiguity. The first two seem to support those philosophical claims about history's apparent assault on memory. They create an image of prevailing and largely traditional conceptions of Jewish history being overwhelmed or corroded by a powerful and irresistible critical form of knowledge. The third conclusion suggests, however, that the relationship between history and memory is messier and altogether more complex. For, while traditional conceptions of Jewish history seem altered by exposure to an alternative and essentially critical historical account, this alternative conception of the Jewish past has not been entirely accommodated on its own terms. The case study shows how, over time and in sometimes subtle ways, memory accommodates history, adapting some aspects of newly acquired knowledge according to pre-existing structures while assimilating others in ways which replace those structures. It suggests that if there is a tension between history and memory, it is not an irreconcilable opposition. Indeed, if this study does confirm any philosophical account of history's relationship with memory, it is closest to that post-modern version in which "both history and memory look like heavily constructed narratives, with only institutionally regulated differences between them" (Zemon-Davis and Starn 1989).

5 References

Carver, R. P. (1974). Two dimensions of tests: Psychometric and edumetric. *American Psychologist*, 29, 512-518.

Dickinson, A.K. and Lee, P.J. (1984). Making sense of history. In A.K. Dickinson, P.J. Lee and P.J. Rogers (Eds.), Learning History (pp. 117-153). London: Heinemann..

Herbst, J. (1985). Review Essay. The Philosophy of History, History and Theory, Beiheft 22, 24(3), 325-336.

Herl, H. E., Baker, E. L., and Niemi, D. (1996). Construct validation of an approach to modeling cognitive structure of U.S. history knowledge. Journal of Educational Research, 89(4), 206-18.

Hoz, R., Bowman, D. and Chacham, T. (1997). Psychometric and edumetric validity of dimensions of geomorphological knowledge which are tapped by concept mapping. Journal of Research in Science Teaching, 34(9), 925-947.

Hoz, R., Tomer, Y. and Tamir, P. (1990). The relations between disciplinary and pedagogical knowledge and the length of teaching experience of biology and geography teachers. Journal of Research in Science Teaching, 27(10), 973-985.

Hoz, R. and Zellermayer, M. (1995). Using the methodology of cognitive mapping to derive representations of teachers' conceptions about writing instruction. Paper presented at the annual meeting of EARLI (Nijmegen, Holland).

Nora, P. (1989). Between memory and history: Les lieux de memoire. Representations, 26, 7-25.

Novak, J.D. and Gowin, D.B. (1984). Learning How to Learn. Cambridge: Cambridge University Press.

Piaget, J. (1971). Biology and Knowledge. Edinburgh: Edinburgh University Press.

Plumb, J. (1969). The Death of the Past. London: Macmillan.

Pomson, A.D.M. and Hoz, R. (1998). Sought and found: Adolescents' "Ideal" historical conceptions as unveiled by concept mapping. Journal of Curriculum Studies, 30(3), 319-337.

Shemilt, D. (1974). Adolescent ideas about evidence in history. In C. Portal (Ed.), The History Curriculum for Teachers (pp. 39-61). Lewes, Sussex: Falmer Press.

Stuart, H.A. (1985). Should concept maps be scored numerically? European Journal of Science Education, 7(1), 73-81.

Wilson, S.M., Shulman, L.S. and Richert, A.E. (1987). '150 different ways' of knowing: Representations of knowledge in teaching. In J. Calderhead (ed.), *Exploring Teachers' Thinking* (pp. 104-124). London: Cassell.

Yerushalmi, Y.H. (1989). Zachor: Jewish History and Jewish Memory. Seattle, WA: University of Washington Press.

Zemon-Davis, N. and Starn, R. (1989). Introduction. Representations, 26, 2.

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TOWARDS AUTOMATIC SUPPORT FOR AUGMENTING CONCEPT MAPS WITH DOCUMENTS

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Abstract. Concept mapping has been used extensively in educational settings as a learning and teaching tool and, more recently, as a knowledge elicitation tool to capture expert knowledge for preservation purposes. In these contexts, electronic concept maps annotated with supplementary multi-media resources can provide a rich source of information. Unfortunately, it can be challenging for users to identify the right resources to attach, especially when dealing with large resource collections. This paper presents ongoing research on methods for easing the annotation task by automatically searching a document library for relevant documents and suggesting them as potential associations for concepts in a map. The paper begins by discussing how concept map structure can be exploited to automatically generate queries to a database of indexed documents, to search for documents to link to the concepts in a map. It then presents methods for indexing documents to improve the search results. The methods for generating queries and indexing documents have been evaluated using two pre-existing expert knowledge models, with encouraging results.

1 Introduction

Concept mapping (Novak & Gowin, 1984) has been widely used in classroom settings to enable students at many different levels to externalize their knowledge for examination and to aid them in constructing new knowledge by linking new, observed concepts to those already known. Likewise, the naturalness of the concept mapping process can enable domain experts to enter their knowledge directly without the need of a knowledge engineer, and the conciseness and structure of concept maps aids others in understanding the entered information. To facilitate electronic concept map construction and sharing, the Institute for Human and Machine Cognition (IHMC) has developed CmapTools, a suite of publicly-available software tools to support generation and modification of concept maps in an electronic form (Cañas et al., 2004). The CmapTools software enables interconnecting maps and annotating them with material such as documents, images, diagrams, and video and audio clips, providing rich, browsable *knowledge models* available for navigation and collaboration across geographically-distant sites. CmapTools has been used in public outreach programs and large institutional memory and expert knowledge preservation tasks for domains including Mars exploration (Briggs et al., 2004), launch-vehicle systems integration (Coffey, 1999), mesoscale weather forecasting (Hoffman et al., 2001), and nuclear power air effluent analysis (Coffey et al., 2004).

To aid the construction of knowledge models, in collaboration with IHMC, we have conducted a long-term effort to develop support tools that can simplify an expert's task in building rich knowledge models. Our past research efforts have focused on the development of "intelligent suggesters" for content-based support, to aid experts in (1) extending their concept maps with new concepts and propositions and (2) determining topics of new concept maps to be added to the knowledge model (Cañas et al., 2002, Leake et al., 2003, Maguitman et al., 2005). Our current focus is to develop support tools to aid in annotating concepts in concept maps with relevant documents. To build knowledge models, experts must construct concept maps, identify resources from available repositories that they want to link to the model, and decide the specific concepts to which the links should be attached. This task can be daunting if the document libraries are large and if the experts have incomplete knowledge of the information contained in each document. Consequently, automatic methods are needed to select candidate documents from a source document library and to suggest target concepts within the model to connect them via navigational links.

This paper begins with a synopsis of specific motivations for this project, in terms of the potential applications for tools to automatically annotate concept maps with documents. It then briefly summarizes our previous work on cognitive models of concept importance judgments, a foundation on which our concept map annotation work builds, before presenting new methods we have developed for the annotation task. It continues by addressing two research questions: (1) how to exploit the structure of concept maps when automatically generating concept-map-based queries, and (2) how to index text documents to facilitate search for relevant documents to annotate concept maps. As steps towards addressing these

questions, we present results from a Web experiment on the indexing power of concepts and linking phrases, present an algorithm for automatic query generation, and present methods for indexing documents and selecting candidate documents from a document library. We conclude with an evaluation of our indexing and search algorithms using two large-scale expert knowledge models.

2 Motivations for Automatic Document Indexing Methods Using Concept Maps

Tools suggesting documents to link to a concept map's concepts can play a valuable role in aiding users building concept maps, by helping them to supplement knowledge in concept maps with links to relevant documents. This paper introduces the CmapAIDE (Concept Map Automatic Indexing for Document Examination) system, a testbed system integrated into CmapTools to support domain experts in finding relevant documents to link to concepts in concept maps. Currently, the system unobtrusively suggests candidate documents for every concept in a concept map for which it finds relevant documents. We envision extending this process to allow users to specify specific sets of concept of interest, for CmapAIDE to perform focused search.

From a broader perspective, we see tools such as CmapAIDE as a step towards the long-term goal of providing general access to information in document libraries. With electronic concept mapping software such as CmapTools facilitating construction and sharing of knowledge models, we expect that expert knowledge models will become more readily available for people to use, either "as-is" or slightly customize for their personal needs. Such public knowledge models could be used to access and navigate electronic documents in libraries within the context of the concept maps, provided automatic methods exist to make it feasible to annotate large collections of concept maps with documents on demand. This approach to information access will enable individuals to use the captured knowledge in the concept maps to find related information and to help understand the information in the documents within the context of the concept map.

Figure 1 shows the possible use cases. In the first, a domain expert constructs a knowledge model and utilizes automatic indexing methods to annotate the model with supplemental material. In the second, a user downloads an expert knowledge model, customizes the model if needed, by revising, removing or adding concept maps, and then uses the model to access and navigate documents.

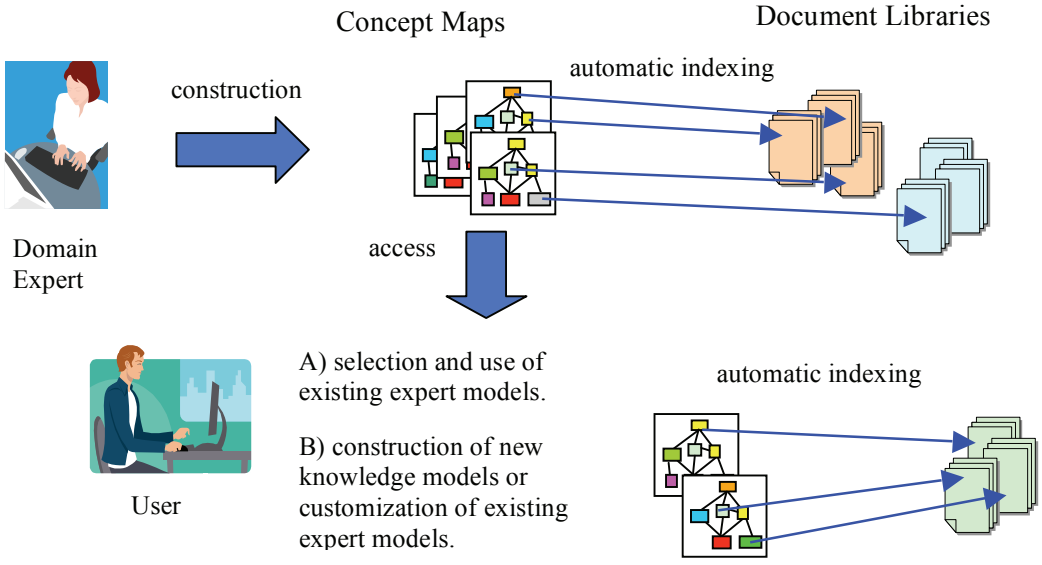


Figure 1: Use cases for automatic indexing.

3 Foundations for the Methods

Our approach to automatic document indexing builds on our previous research on analyzing the relationship of concept map structure and concept importance. Unlike text documents, concept maps have a rich structure that may be exploited by search and navigation tools. In two previous human-subjects studies, we examined how observed structure influences people's understanding of concept importance in already constructed maps and how concept map structure reflects the map-builders' own judgments of concept importance. In the first study, subjects observed concept maps with variations in their topology and layout, including changes in a concept map's number of outgoing and incoming connections, distance to the root concept, and layout differences. When labels of the concepts were replaced with artificial words to exclude domain knowledge about concept importance, structure influenced assessment of concept importance, but layout did not. In the second study, subjects constructed a concept map on a topic of their choice before ranking the importance of selected concepts extracted from their map, whose connectivity or distance to the root concept varied, in order to study how the topology selected by the author related to the author's choice of important concepts in describing the map's topic. Analysis of the results from both studies showed that topology alone is a good indicator (human judgments were closely related to topological factors, with few exceptions), making structure useful to predict people's assessment of concept importance in concept maps and hence to extract topic-relevant information from concept maps. In addition, the studies evaluated the ability of three candidate models to predict concept importance in concept maps based only on structural factors. The best fit was achieved by the Hub-Authority-Root-Distance (HARD) model, which was shown to be sufficient to account for most subjects' importance assignments. The HARD model, shown in Table 1, is used for concept importance weighting in CmapAIDE. The model takes hub (h), authority (a), and upper values of a concept into consideration, as well as three model parameters (α, β, γ) used for tuning, to compute the importance of a concept. Full details on the studies and models are available in (Leake et al., 2004a, Reichherzer & Leake, 2006).

Hub Authority Root Distance (HARD)	$W(C) = (\alpha \cdot a + \beta \cdot h + \gamma \cdot u),\ \gamma \geq 0$

Table 1: Model for assessing concept importance.

4 Retrieval Performance Using Concept Keywords versus Linking Phrase Keywords

The prior research described in Section 3 showed the value of structure in predicting concept importance, and provides a basis for using structural factors to weight concept importance for retrieval. Another important question for generating queries from concept maps is the relative value of keywords extracted from concepts or extracted from links as terms for information retrieval and indexing. Informal results suggest that the prevalence of common linking phrases in concept maps (e.g., *has*, *includes*, *is composed of*) may make linking phrases less informative and less useful for systems that do not employ natural language processing techniques to determine their meaning and the role they play in a concept map. To provide a more definitive result, here we present a new empirical study, expanding on (Leake et al., 2004b), to examine the retrieval power of linking keywords and concept keywords as well as keywords from multiple model-selected concepts. This study involved (1) selecting concepts and links from a concept map, (2) generating Web queries from the keywords of the concept and link labels in different ratios, (3) retrieve Web documents matching the keywords and (4) comparing the documents to the target concept map. To measure similarity between a concept map and a Web document and the retrieval power of keywords from concept maps, we use variants of the standard recall and precision measures, defined with respect to a target concept map M and a Web document D. Table 2 depicts these measures. The sets D, M, M_C, and M_L consist of keywords extracted from the Web documents and a concept map respectively, with M_C containing keywords from concept labels and M_L containing keywords from link labels only. Q consists of the terms that appear in a query submitted to a search engine, which are considered in the measures to determine the recall and precision values with respect to keywords other than the query terms.

Recall	$R(Q,M,D) = \frac{\lvert(M \cap D) - Q\rvert}{\lvert M - Q\rvert}$	$R_C(Q,M,D) = \frac{\lvert(M_C \cap D) - Q\rvert}{\lvert M_C - Q\rvert}$	$R_L(Q,M,D) = \frac{\lvert(M_L \cap D) - Q\rvert}{\lvert M_L - Q\rvert}$
Precision	$P(Q,M,D) = \frac{\lvert(M \cap D) - Q\rvert}{\lvert D - Q\rvert}$	$P_C(Q,M,D) = \frac{\lvert(M_C \cap D) - Q\rvert}{\lvert D - Q\rvert}$	$P_L(Q,M,D) = \frac{\lvert(M_L \cap D) - Q\rvert}{\lvert D - Q\rvert}$

Table 2: Metrics for measuring precision and recall with respect to a target concept map.

In our study, ten randomly selected concept maps from each of the Mars 2001 (Briggs et al., 2004) and Storm-LK (Hoffman et al., 2001) expert knowledge models were considered to compute Web queries and compare matching Web pages with concept maps. In each experiment, a set of queries was computed, differing in both the ratio of concepts and linking phrases and in the concepts from which the keywords were drawn. The set of combinations considered is shown in Table 3, which reports the results from the study. The query type column indicates the type of query that was generated and submitted to the Google search engine. CCC indicates that keywords were extracted from a concept and two of its connected concepts, LCL indicates that keywords were extracted from a concept and two connected linking phrases, and LLL indicates that keywords were extracted from three linking phrases connected to a concept. For each concept in each map in the knowledge model (provided the concept was connected to more than one other concept) all types of queries were generated. The results were averaged over all concepts considered. All other types of queries considered in the experiment, involve the three topological models. About 25% of the highly ranked concepts as determined by the models were selected to generate Web queries, considering all possible combinations for selecting query keywords. The results were averaged across the different combinations. Recall, calculated as in Table 2, indicates the keywords that were recalled from the Web documents. Precision measures how precisely the document and concept map match. The precision value can be small, especially if retrieved Web documents are large, containing many more keywords than the concept map.

Model	Query Type	R(Q,M,D)	R_C(Q,M,D)	R_L(Q,M,D)	P(Q,M,D)	P_C(Q,M,D)	P_L(Q,M,D)
Mars 2001	CCC	0.346	0.345	0.346	0.063	0.049	0.015
	LCL	0.278	0.253	0.372	0.044	0.034	0.011
	LLL	0.192	0.142	0.419	0.025	0.015	0.011
	CCC CRD	0.410	0.414	0.400	0.135	0.110	0.031
	CCC HARD	0.434	0.440	0.417	0.150	0.117	0.034
	CCC PF	0.462	0.471	0.445	0.153	0.121	0.033
Storm-LK	CCC	0.427	0.435	0.418	0.057	0.048	0.010
	LCL	0.317	0.303	0.402	0.053	0.044	0.010
	LLL	0.173	0.142	0.344	0.030	0.022	0.009
	CCC CRD	0.510	0.518	0.507	0.125	0.104	0.024
	CCC HARD	0.454	0.463	0.451	0.114	0.095	0.021
	CCC PF	0.515	0.524	0.507	0.131	0.109	0.025

Table 3: Results of the empirical study to search for related Web documents using concept and linking phrase keywords.

The results support that concept keywords are generally more useful in retrieving relevant Web documents as measured by recall and precision. The recall and precision values for CCC queries are higher than for LCL and LLL queries. It is important to note that queries including terms from linking phrases generally retrieve documents containing terms from other linking phrases, but not as many terms from other concepts. This is particularly notable for queries containing linking phrase keywords only. In addition, searching for relevant Web documents using highly ranked concepts based on our topological models returns better results than using any three directly-linked concepts from a map. The results support the use of concept-based queries, as favored by the models, to generate contextual information for searching related documents. This guides the decision of the design of our automatic query generation method to use concept-based queries.

5 An Algorithm for Automatic Query Generation to Find Relevant Documents

The success of automatic query generation depends on the selection of useful keywords. For the keywords to achieve good recall, the terms in the query must reflect both (1) the target concept to which retrieved documents will be linked, and (2) topic descriptors that support disambiguation of the meaning of the target concept—In concept maps, concepts rely on the context provided by the concepts and connections to define their meaning.

We have developed an algorithm which uses the HARD model as a basis for determining the context keywords of a search query involving a specific concept in a concept map. To generate a query to search for documents relevant to a target concept, first, the top model-favored concepts are selected to build a query context. Keywords from the concepts in the query context are extracted and weighted using a simple frequency model in which each keyword's weight is set to its number of occurrences. The weights of the target concepts are assigned a constant weight. The weighted keywords create a query keyword vector (Baeza-Yates & Ribeiro-Neto, 1999) that can be used to search for relevant documents, indexed with a vector model using a cosine similarity measure. Table 4 summarizes the algorithm used to search for relevant documents.

ALGORITHM:
INPUT:
M: a concept map.
c_t: a target concept
L: a library of indexed documents
τ: threshold for selecting documents from *L*
w_t: the weights of keywords from the target concepts
OUTPUT:
a list *R* of ranked documents *D* from library *L*
BEGIN
//topological analysis
Use the HARD model to assign a weight *W(c)* to each concept *c* in the concept map *C*
Rank concepts according to their weights *W(c)*.
// query formation
Select top 25% of the model-favored concepts; extract keywords to generate a query context.
For each keyword k in query context:
compute keyword weight W(k) as the frequency of k in the query context.
For each keyword k in the target concept c_t:
assign keywords W(k) the fixed weight w_t.
Combine keywords to form a query vector *Q*.
//search
for all documents *D* from *L* do:
compute cosine similarity *S* between *Q* and *D,*
if $S > \tau$, add *D* to list of results *R*.
rank *R* according to similarity *S*, and return it.
END

Table 4: An algorithm for searching relevant documents.

6 Document Indexing to Facilitate Retrieval

Just as concept maps may be analyzed for important concepts, documents may be analyzed to develop indices to facilitate retrievals useful for the task of annotating concept maps. In well-written documents, authors present their thoughts and ideas in a structured form to support readers' understanding. The smallest unit of information tends to be a sentence, followed by a paragraph which discusses a concept, presents an idea, or addresses a question. Large documents are likely to cover a variety of different ideas and topics. Thus, if the goal is to link concept maps to text documents, considering the entire document in the search for relevant information may be less useful than considering smaller units of information.

Automatic text decomposition can aid in finding text *segments* as neighboring units exhibiting internal consistency that can be distinguished from the remaining text. Text relationship maps (Salton et al., 1996) can identify text *themes* as semantically homogenous text units within the document as well as identify relationships between segments and themes and the role they play within the entire document. In addition, to segments and themes, we consider *synopses* as sets of units that relate to many other, non-adjacent units in the document. From themes, segments, and synopses, keywords can be extracted to index documents to support effective access to information in documents. Figure 2 depicts a text relationship map for a sample document consisting of eighteen paragraphs, each considered a separate unit. The solid lines mark neighboring units, forming text segments. Dashed lines indicate themes, consisting of non-adjacent paragraphs that are similar to each other, while dotted lines indicate synopses.

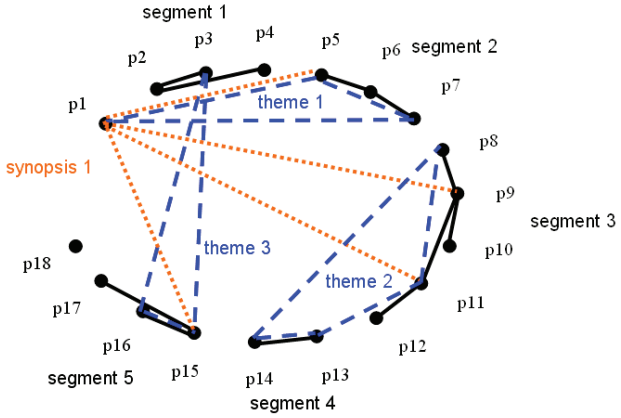


Figure 2: A text relationship map for a sample document.

To compute a text relationship map, we use a keyword vector model computed from the keywords in a unit and apply cosine similarity. The weights for the keyword are computed taking into consideration both the keyword distribution within the units of a document and the keyword distribution throughout the documents of the library, as defined in Table 5. In the formula, the weight of keyword k in document i, considers the frequency of k in i, adjusted by the inverse frequency of k occurring in the units of document i, as well as k occurring in other documents. N_U is the number of units in i and n_{Uk} is the number of times k occurs in units of i. N_L is the number of documents in the document library L, while n_{Lk} denotes the number of times k occurs in documents in L.

$$w_{ik} = \frac{tf_{ik} \cdot \log(N_U/n_{Uk}) \cdot \log(N_L/n_{Lk})}{\sqrt{\sum_j (tf_{ij})^2 \cdot (\log(N_U/n_{Uk}))^2 \cdot (\log(N_L/n_{Lj}))^2}}$$

Table 5: Formula for computing the weight of a keyword in a document.

Once segments, themes, and synopses have been computed, keywords can be extracted and the document indexed by the corresponding keywords and their weights. A document may be indexed multiple times under different sets of keywords corresponding to the segments, themes, and synopses to make it more likely that relevant information embedded in large documents can be identified.

7 Evaluation of the Overall System

We have implemented the methods described in the previous sections in CmapAIDE. The tool pre-processes documents to extract information for comparison with captured knowledge in concept maps. We evaluated the combined indexing and search algorithm using two expert knowledge models that consist of a large number of concept maps linked to several hundred documents. Most of the documents are Web pages, containing text, images, or movie clips. To measure the performance of our methods, we treated the documents annotating the concepts in each expert knowledge model as if removed from the model and collected into a pool of documents for the system to search. For each concept in the original model, which was annotated with one or more documents, we then ran CmapAIDE to test how often CmapAIDE's suggestions included the documents originally chosen. We considered three conditions, in which CmapAIDE generated ranked lists of 5, 10, 20 suggestions. For example, if the expert linked a document entitled "Radiation" to the concept "Human Health & Performance", and CmapAIDE ranks that document eighth on its list of suggestions for that concept, it is a failure for the list of length 5, but a success for the lists of lengths 10 and 20. For the experiment, we varied the influence of contextual information in

retrieving relevant information, considering either both, the target concept (t_c) and topic concepts (T), only topic concepts (T), or only the target concept (t_c).

To compute a document index, using the methods specified above, we focused on applying segmentation to generate an index for the documents; subsequent research will also consider indexing documents based on the extracted themes and synopses. The similarity threshold for computing segments was chosen to be low, favoring large segments in the document. Among the annotation of the knowledge models, only text documents with more than 200 words along with their corresponding concept maps were considered for the performance test. For the Mars 2001 knowledge model (Briggs et al., 2004), performance was tested on a total of 72 concept maps and 159 indexed text documents and for the Storm-LK (Hoffman et al., 2001) knowledge model, the performance test considered 26 concept maps and 95 indexed text documents.

The results show that including the keywords from both topic and target concepts is critical in retrieving relevant text documents with which a concept map may be annotated. When considering lists of 10 to 20 suggestions, CmapAIDE discovered about 70% to 84% of the text annotations as chosen by the experts. When tested with and without indexing documents using segmentation, we recorded an improvement of up to 4% when segmentation is applied. Ideally, we want the system to list the expert's selected text annotations among the top 5 suggestions, facilitating selection. Consequently, subsequent research efforts will focus on improving the selection of the suggestions, considering measures of keyword correlations for closer comparison between the keywords in the target document and concept map. While the current experiment provides a good basis for performance evaluation, we have no complete measure for how many of the suggested annotations may be valid. The experts may have overlooked including some of the text annotations as suggested by CmapAIDE. Thus, the results suggest a lower bound on performance.

Model		**Number of suggestions considered**								
		5			**10**			**20**		
	variations of topic concepts T and target concept t_c in a query	**both**	**no T**	**no t_c**	**both**	**no T**	**no t_c**	**both**	**no T**	**no t_c**
Mars 2001	average matching ratio	0.61	0.25	0.18	0.70	0.31	0.26	0.7	0.35	0.30
	correct suggestions (%)	62.8	30.4	19.4	72.9	35.6	29.6	79.4	38.5	34.4
Storm-LK	average matching ratio	0.57	0.24	0.22	0.75	0.39	0.33	0.87	0.39	0.49
	correct suggestions (%)	48.6	27.5	20.2	69.7	39.4	30.3	84.4	40.4	43.1

Table 6: Results from an evaluation experiment testing performance of CmapAIDE.

8 Summary

This paper presents the design and current results on CmapAIDE, a prototype system to support domain experts in annotating concepts maps with information from document libraries. The same system could also be used in concept-map-based interfaces for navigating documents from a large document library. The system has been evaluated with encouraging initial results. We are continuing to expand and refine the methods to improve system performance and to integrate the system into CmapTools. In addition, we plan to supplement the automated evaluation of the prototype system with a human-subjects study.

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References

Baeza-Yates, R. and Ribeiro-Neto, B. (1999). Modern Information Retrieval, New York: ACM Press.

Briggs, G., Shamma, D., Cañas, A., Carff, R., Scargle, J., and Novak, J. D. (2004). Concept maps applied to Mars exploration public outreach. In Cañas, A. J., Novak, J. D., and González, F., (Eds.), Concept Maps: Theory, Methodology, Technology. *Proceedings of the First International Conference on Concept Mapping*, Pamplona, Spain: Universidad Pública de Navarra.

Cañas, A., Carvalho, M., Arguedas, M. Mining the Web to suggest concepts during concept mapping: Preliminary results. (2002). In *XIII Simpósio Brasileiro de Informática na Educação*, SBIE UNISINOS.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M., & Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: Theory, Methodology, Technology, *Proceedings of the First International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W. (1999). Institutional memory preservation at NASA Glenn Research Center. Unpublished technical report, NASA Glenn Research Center, Cleveland, OH, USA.

Coffey, J., Eskridge, T., and Sanchez, D. P. (2004). A case study in knowledge elicitation for institutional memory preservation using concept maps. In Cañas, A. J., Novak, J. D., and González, F., (Eds.), Concept Maps: Theory, Methodology, Technology. *Proceedings of the First International Conference on Concept Mapping*, Pamplona, Spain: Universidad Pública de Navarra.

Hoffman, R. R., Coffey, J. W., Ford, K. M., and Carnot, M.-J. (2001). Storm-lk: A human-centered knowledge model for weather forecasting. *Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society*, Minneapolis, MN, USA.

Leake, D., Maguitman, A., Reichherzer, T. (2004a). Understanding Knowledge Models: Modeling Assessment of Concept Importance in Concept Maps. *Proceedings of the Twenty-Sixth Annual Conference of the Cognitive Science Society*, Chicago, Illinois, 795-800.

Leake, D., Maguitman, A., Reichherzer, T. Cañas, A., Carvalho, M., Arguedas, M., Eskridge, T. (2004b). "Googling" from a Concept Map: Towards Automatic Concept-Map-based Query Formation. In Cañas, A. J., Novak, J. D., and González, F., (Eds.), Concept Maps: Theory, Methodology, Technology. *Proceedings of the First International Conference on Concept Mapping*, Pamplona, Spain: Universidad Pública de Navarra.

Leake, D. B., Maguitman, A., Reichherzer, T., Cañas, A.J., Carvalho, M. Arguedas, M., Brenes, S., Eskridge, T. (2003). Aiding Knowledge Capture by Searching for Extensions of Knowledge Models. *Proceedings of K-Cap-03*. Sanibel Island, Florida, ACM Press.

Maguitman, A., Leake, D., Reichherzer, T. (2005). Exploiting Rich Context: An Incremental Approach to Context-Based Web Search. In *Proceedings of Fifth International and Interdisciplinary Conference on Modeling and Using Context (CONTEXT-05)*, Paris, France, Lecture Notes in Computer Science, Vol. 3554, Springer Verlag, pp. 254-267.

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Reichherzer, T., Leake, D. (2006). Understanding the Role of Structure in Concept Maps. *Proceedings of the Twenty-Eighth Annual Conference of the Cognitive Science Society*, Vancouver, Canada (in press).

Salton, G., Singhal, A., Buckley, C., and Mitra, M. (1996). Automatic text decomposition using text segments and text themes. In *UK Conference on Hypertext*, pages 53-65.

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TRABAJANDO CON MAPAS CONCEPTUALES EL TEMA DE LA PROPORCIONALIDAD DE 2º DE EDUCACIÓN SECUNDARIA OBLIGATORIA (E.S.O.)

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Abstract: En este trabajo se presenta una experiencia acerca de la utilización de los mapas conceptuales (MMCC) en un tema de matemáticas. En concreto, el objetivo principal ha sido detectar en los estudiantes los indicadores propios del aprendizaje significativo (AS) a través del análisis de MMCC, en un contexto en el que los estudiantes de 2º de E.S.O. de la ikastola San Fermin han trabajado el tema de la proporcionalidad desde el área de las matemáticas. Previendo que los MMCC constituyen una herramienta inmejorable para potenciar el AS de los estudiantes en detrimento del aprendizaje memorístico (AM), esta herramienta ha sido utilizada en el diseño y la implementación de la instrucción referente al tema, así como, en la evaluación del conocimiento adquirido por los estudiantes. Los resultados obtenidos muestran la eficacia de los MMCC para el logro de un aprendizaje más significativo en los estudiantes considerados. Esta consideración se ha basado en los criterios para identificar los indicadores del AS en la valoración de los MMCC realizados por los estudiantes. Se han detectado, asimismo, diferentes patrones de MMCC que podrían ser considerados como valiosos predictores del aprendizaje.

1 Introducción: Consideraciones teóricas

En los últimos treinta años se han dado cambios muy profundos en la enseñanza de las matemáticas. La comunidad internacional de expertos en didáctica de las matemáticas sigue realizando esfuerzos por encontrar moldes adecuados, por lo que está claro que vivimos aún actualmente una situación de experimentación y cambio (Guzmán, 1993). Por una parte, nuestras sociedades occidentales, cada vez más desarrolladas científica y tecnológicamente, exigen un nivel alto de conocimiento matemático y valoran éste como uno de los conocimientos más importantes, por no decir el que más, pero por otra, cada día es mayor la conciencia, avalada por los datos recogidos por diferentes estudios como el Informe PISA 2003 (Programme for International Student Assessment), de que nuestros estudiantes no están matemáticamente alfabetizados (Rico, 2005).

Paralelamente se han producido aportaciones muy relevantes acerca del aprendizaje humano, aportaciones teóricas que han tenido gran influencia en el mundo de la educación. Una de ellas es la teoría educativa de Novak (1982) que propone que para conseguir un aprendizaje más activo y eficaz de los alumnos y para posibilitar que se produzcan en ellos cambios en la comprensión de la actividad matemática, hay que relacionar lo que ya se sabe acerca de la naturaleza del conocimiento y del aprendizaje humano con la enseñanza de las matemáticas. Su teoría de la educación sostiene que el AS es el resultado de la integración constructiva del pensamiento, el sentimiento y la acción que conducen a la capacitación humana para el compromiso y la responsabilidad. Desde su perspectiva constructivista, Novak (1988) hace hincapié en el concepto de AS tal y como Ausubel (1976) lo plantea en su teoría de la asimilación.

Novak (1998) señala que un problema fundamental en el aprendizaje de las matemáticas es que la mayor parte de los materiales de instrucción son conceptualmente poco claros, es decir, no presentan los conceptos ni las relaciones conceptuales necesarios para comprender el significado de las ideas matemáticas en cuestión. A la hora de diseñar e implementar instrucciones escolares que cumplan las condiciones del AS, se hacen necesarios instrumentos que faciliten dicho aprendizaje y el mapa conceptual (MC) es precisamente uno de ellos. Algunos de los trabajos presentados y publicados en las Actas correspondientes al First International Conference on Concept Mapping (Pamplona, 2004) se refieren a la aplicación de los MMCC en temas de matemáticas, como por ejemplo los trabajos de Afamasaga-Fuata'i (pp.13-20) en los que se subraya la utilidad de los MMCC como instrumentos que ayudan a los estudiantes a desarrollar una comprensión mayor y más profunda de ciertos tópicos matemáticos seleccionados, o el trabajo de Serradó, Cardeñoso y Azcárate (pp.595-602) en el que se resaltan los MMCC como instrumentos que facilitan la evaluación diagnóstica de los obstáculos surgidos durante el proceso de enseñanza y aprendizaje del conocimiento matemático, así como el valor de los MMCC como fuente de información que fomenta el desarrollo profesional del docente.

Desde nuestra experiencia como docentes uno de los temas más sugerentes en la enseñanza de las matemáticas es el de la proporcionalidad. Desde sus orígenes la proporcionalidad ha estado presente en el estudio del mundo que rodea al hombre. Así, por ejemplo, al no poder medir directamente distancias, el método ha sido buscar recursos para compararlas. Vemos aparecer la noción primero en Astronomía y después en las Ciencias en general, tanto a nivel de definir nuevas magnitudes como para expresar relaciones numéricas, trabajar con índices, constantes o tasas. Así pues, la proporcionalidad es un concepto básico en las Matemáticas y es un tema de gran importancia en el currículo escolar (Fiol y Fortuny, 1990), ya que está relacionado con la mayoría de los contenidos de Matemáticas y con los de otras asignaturas como Física, Biología, Química, etc.

En cuanto al desarrollo cognitivo encontramos en la teoría de Piaget (Piaget e Inhelder, 1972) una caracterización del mismo, ya que en la misma el razonamiento proporcional está indicado como la señal del nivel de las operaciones formales en los estadios de desarrollo definidos. Piaget abordó este tema principalmente en sus estudios referidos a la probabilidad, las leyes físicas y las relaciones espaciales. Según él, la noción de proporción se encuentra en el nivel de las relaciones formales, es decir, que las operaciones no se realizan directamente sobre los objetos sino que se trata de operaciones de operaciones. Siguiendo las ideas de Freudenthal (1978) los problemas de razonamiento proporcional pueden clasificarse en problemas que tienen razones internas y problemas que tienen razones externas. Las razones internas son razones entre términos pertenecientes a una misma magnitud, y las razones externas son comparaciones entre cantidades de dos diferentes magnitudes.

De acuerdo con lo anteriormente expuesto, pretendemos en este trabajo resaltar la utilización del MC como instrumento facilitador del aprendizaje significativo y en concreto, su utilización en la enseñanza/aprendizaje de la noción de proporcionalidad y los problemas correspondientes a la misma, haciendo hincapié por una parte en la razón entre cantidades diferentes de la misma magnitud y por otra, en la relación proporcional que puede existir entre dos magnitudes diferentes y las diversas formas en las que esta relación proporcional puede ser expresada.

2 Diseño y desarrollo de la investigación

La elaboración del trabajo que presentamos ha sido posible gracias a la participación en uno de los subgrupos pertenecientes al equipo de investigación que desarrolló el proyecto GONCA (González y Cañas, 2004), financiado por el Departamento de Educación del Gobierno de Navarra. El proyecto GONCA respondía, entre otras cosas, al objetivo de evaluar la influencia que tiene la construcción de los MMCC, considerados como instrumentos de evaluación, enseñanza y aprendizaje, en el desarrollo del AS frente al aprendizaje memorístico. Así mismo, pretendía la utilización del programa informático CmapTools (Cañas *et al*, 2004) para la elaboración de los MMCC por parte de los estudiantes. El software CmapTools fue desarrollado en el Institute for Human and Machine Cognition para permitir a los usuarios la construcción de mapas conceptuales a través de una interfaz muy sencilla y para posibilitar que los MMCC se pudieran guardar fácilmente en servidores que son accesibles para cualquiera en Internet.

En este trabajo queremos contrastar que el MC es un instrumento muy útil para diseñar un módulo instruccional (MI) innovador referente al tema de la proporcionalidad, así como para averiguar los conocimientos previos de los estudiantes en relación a este tema y analizar cual es la evolución de su aprendizaje. En este sentido, nos vamos a basar en el análisis comparativo de los mapas realizados por los estudiantes antes y después de la instrucción, siguiendo el modelo presentado por Guruceaga y González (2004) y según el cual podemos fijarnos en diferentes aspectos que presentan los MMCC (ver Tabla 1), de forma que el MC de un estudiante va a ser un instrumento que nos revela el grado de AS llevado a cabo por él, o por el contrario, si su aprendizaje ha sido menos significativo y más memorístico/mecánico. El análisis de los mapas realizados por los estudiantes también nos servirá para ver la posibilidad de agrupar los MMCC en varios grupos según características y tendencias comunes presentes en los mismos.

Este trabajo se realizó a lo largo del curso 2002-2003 en el centro concertado San Fermin Ikastola de la comarca de Pamplona. Se trata de un centro que escolariza a sus estudiantes en euskera y que acoge tanto niveles de infantil y primaria como de secundaria obligatoria y bachillerato. En concreto, la investigación fue llevada a cabo en el nivel de 2º de la E.S.O., en dos de las cuatro aulas de este nivel, y se trabajó el tema de la proporcionalidad desde el área de Matemáticas.

Tabla 1. Indicadores de aprendizaje.

Aprendizaje más significativo	Aprendizaje más memorístico/mecánico
• Diferenciación clara entre conceptos y palabras de enlace; aparece la direccionalidad en las relaciones entre conceptos	• No hay una diferenciación clara entre conceptos y palabras de enlace; no aparece la direccionalidad en las relaciones entre conceptos
• Utilización de la mayoría de los conceptos	• Utilización de un número menor de conceptos
• Hay una disminución de proposiciones erróneas	• Aparecen frecuentemente proposiciones erróneas: jerarquías conceptuales no lógicas
• Existe una organización jerárquica coherente desde el punto de vista de la naturaleza inclusiva de los conceptos	• Aparece una organización jerárquica no correcta desde el punto de vista de la inclusividad de los conceptos
• Se identifica el concepto más inclusivo	• No se identifican los conceptos más inclusivos
• Aparece algún ejemplo de supraordenación en algún concepto de naturaleza inclusiva • Los conceptos más inclusivos presentan una compleja diferenciación progresiva • Aparecen menos relaciones lineales entre conceptos o no aparecen en absoluto	• Aparecen relaciones lineales, estructuras en cadena entre conceptos
• Aparecen numerosos enlaces cruzados reveladores de reconciliaciones integradoras de calidad	• Se establecen pocos y erróneos enlaces cruzados, signo de unas reconciliaciones integradoras deficientes

En cuanto al diseño del MI y para facilitar el AS, se ha tenido en cuenta la recomendación de Ausubel (1976) de considerar lo que los estudiantes ya saben con respecto al tema a trabajar en el aula. Los mapas previos realizados por los estudiantes se han utilizado para conocer el punto de partida de los mismos. Asimismo, Ausubel propone que al inicio de la instrucción se presenten los conceptos más inclusivos en referencia al tema a tratar, para trabajar después los conceptos más específicos. De ahí la necesidad de clarificar qué conceptos van a estar implicados en la instrucción a realizar, qué significado van a tener estos conceptos, cuáles son las relaciones jerárquicas y reconciliaciones entre los mismos y cuál es la relación entre este marco de referencia y lo que los estudiantes ya saben. Novak recomienda elaborar un MC de referencia, donde se estructuren los conceptos implicados, inclusivos y específicos, relacionados con el tema elegido, en este caso, la proporcionalidad. Una vez elaborado el MC de referencia (ver Figura 1), se pueden identificar los núcleos conceptuales más significativos en relación a los cuales se diseñarán las actividades y el orden temporal de las mismas.

La estructura de la instrucción se adaptó del Project LEAP (Learning about Ecology, Animals and Plants, 1995). En este planteamiento las actividades se agrupan en tres fases: introducción, focalización y resumen. En la primera se presentan y se trabajan los conceptos más inclusivos, a continuación se trabajan las diferenciaciones progresivas y reconciliaciones más significativas, y para terminar se establecen aplicaciones de la información manejada a lo largo de la instrucción. En el diseño de las actividades que conforman este módulo, que se escribió en euskera para su implementación directa en el aula, se utilizaron actividades publicadas en diferentes propuestas didácticas. En cuanto a la metodología, los estudiantes trabajaron individualmente en las fases de introducción y de resumen, y en pequeños grupos de cinco durante la fase de focalización. El trabajo en grupo no era la forma habitual de trabajo en el aula en las clases de matemáticas de la E.S.O., pero en general, el alumnado tenía una actitud positiva hacia el trabajo en equipo, salvo excepciones de casos muy individualistas y que aportaron poco al grupo. Durante la instrucción los estudiantes también realizaron más MMCC y para ello se sirvieron del software CmapTools, instalado en los ordenadores del aula de informática del centro escolar.

3 Discusión de los resultados

En esta investigación fueron analizados los MMCC previos y posteriores a la implementación de un MI innovador sobre la proporcionalidad, realizados por 32 estudiantes de los 63 que participaron en dicha experiencia. Los conceptos que se utilizaron para la realización de los MMCC de los estudiantes fueron los mismos que se utilizaron para la elaboración del mapa de referencia de la investigación, 25 conceptos tanto en el primer mapa como en el segundo. Tras el análisis de los mapas realizados podemos decir que la estructura cognitiva de los estudiantes se refleja más ordenada y jerarquizada después de la instrucción. Hay una utilización de un número mayor de conceptos para la elaboración del mapa después de la instrucción y la estructura cognitiva se ha enriquecido con la

incorporación del concepto ***razón***, cuya naturaleza inclusiva ha quedado reflejada correctamente en más de la mitad de los casos. Basándonos en la tendencia que se aprecia entre los dos mapas comparados en cada caso, en la relación entre proposiciones erróneas o imprecisas y las proposiciones totales, podemos también decir que la estructura cognitiva de los estudiantes es más lógica. En los mapas posteriores a la instrucción se aprecia una tendencia a clarificar más y mejor los niveles jerárquicos, sobre todo, los superiores. En muchos casos ha habido una clara diferenciación de conceptos como ***relación proporcional*** y ***proporción***, es el caso del 56% de los estudiantes, que han diferenciado uno u otro concepto. Estos conceptos son inclusivos en el mapa de referencia. Los enlaces cruzados que aparecen en los mapas posteriores nos indican que dos tercios de los estudiantes han reconciliado de forma integradora las diferentes formas de expresión de los dos tipos de relación proporcional. Además, podemos decir que los tres estudiantes que han diferenciado los conceptos ***relación proporcional*** y ***proporción*** también los han reconciliado, puesto que han definido una relación correcta entre ambos.

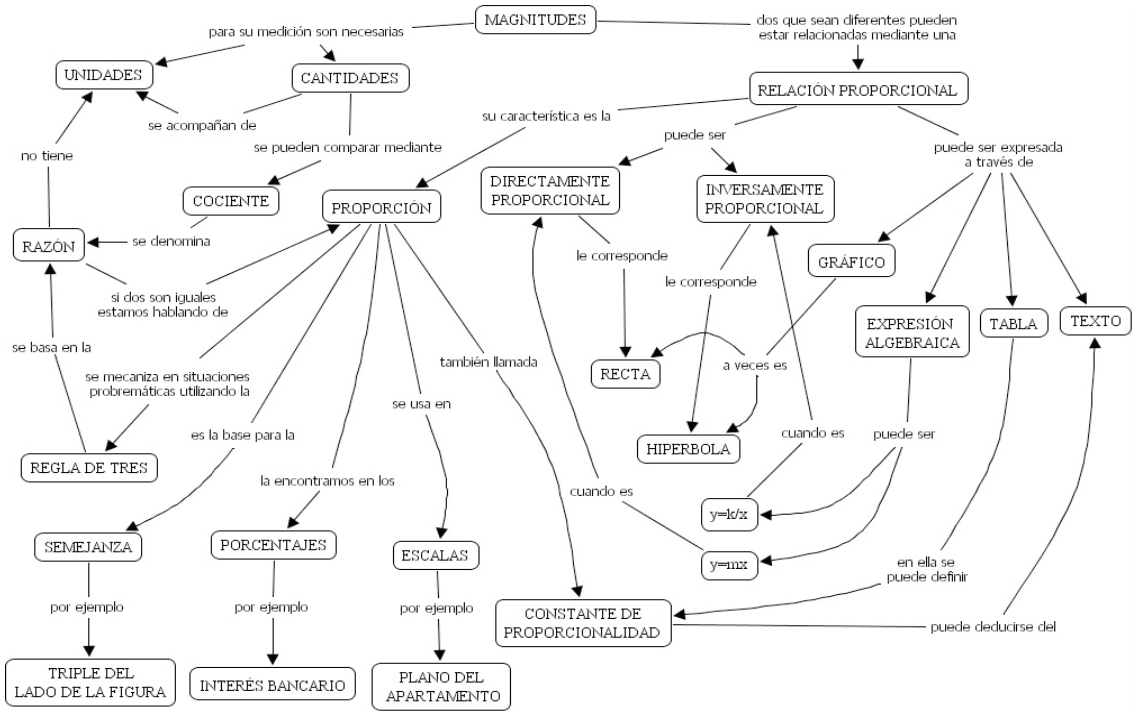


FIGURA 1. Mapa conceptual de referencia. (Pozueta, 2003)

Es interesante señalar en esta discusión la existencia de tres tendencias marcadas en los MMCC realizados por los estudiantes tras la instrucción. Este mismo hecho ha sido resaltado con anterioridad en un trabajo de González (1997). En dicho trabajo se muestran tres grupos diferentes de MMCC realizados por los estudiantes, según características comunes que aparecen en los mismos. En el caso que nos ocupa, podemos ver estas tendencias con características similares. Así, podemos ver una primera tendencia en tres de nuestros estudiantes donde se puede ver claramente el cambio que supone la nueva estructura del mapa realizado por el estudiante y que se asemeja muchísimo al mapa de referencia utilizado. Podemos apreciar los mapas anterior y posterior del estudiante I.I. (ver Figura 2 y Figura 3) como representante de este grupo de estudiantes. Este estudiante ha utilizado 14 conceptos en su mapa inicial, mientras que ha utilizado los 25 en el final.

Se puede ver cómo ha incorporado el concepto ***razón*** dándole un significado pleno al relacionarlo correctamente tanto con la ***proporción*** como con la ***relación proporcional***. La relación proporcional adquiere el nivel jerárquico que le corresponde y quedan perfectamente definidas en otro nivel inferior las cuatro formas de expresión que se han trabajado en el MI para los dos tipos de proporcionalidad: la descripción verbal, la tabla, la fórmula y la gráfica. Están también reflejadas las relaciones transversales que se dan entre estos tipos de expresión. Asimismo, presenta en otro nivel jerárquico las tres situaciones matemáticas trabajadas en el módulo como ejemplos de proporcionalidad directa.

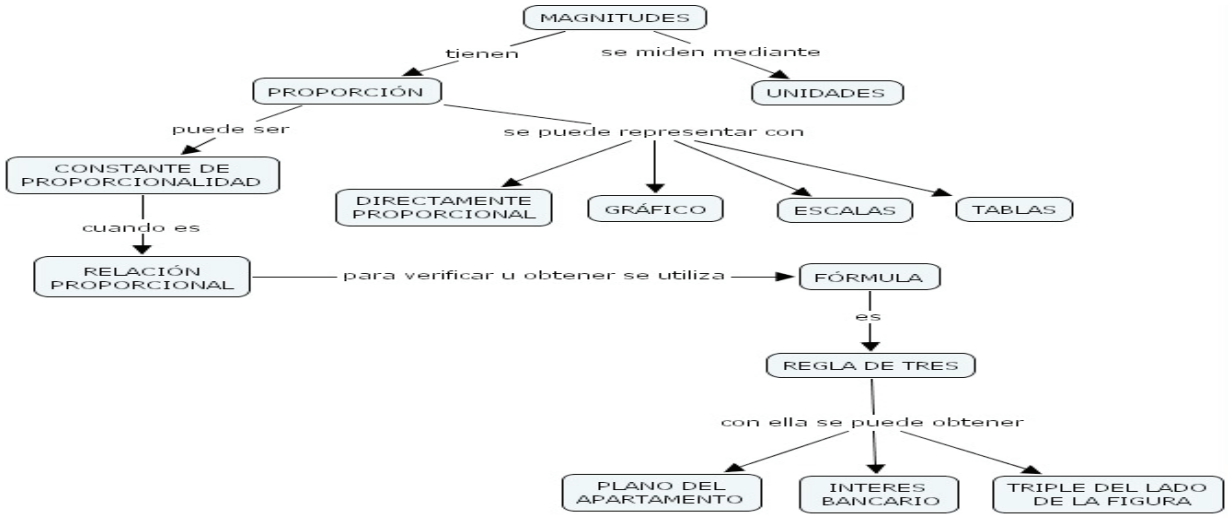


FIGURA 2. MAPA INICIAL DE I.I.

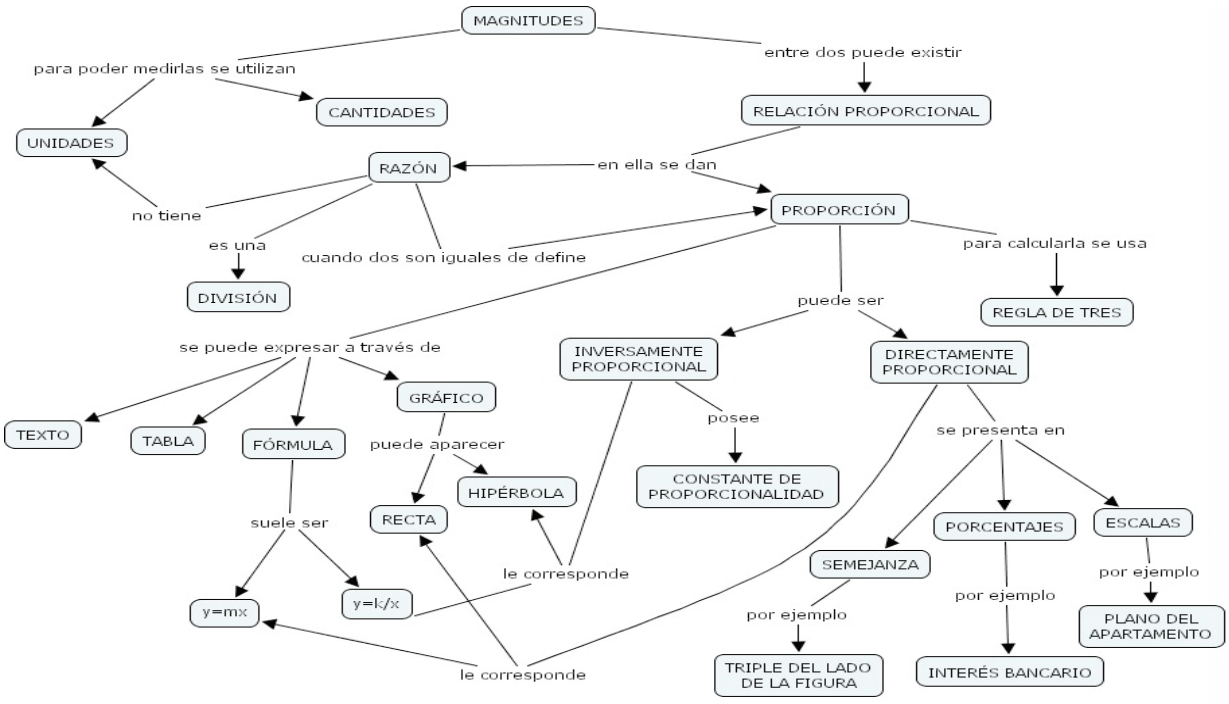


FIGURA 3. MAPA FINAL DE I.I.

Tenemos una segunda tendencia que queda reflejada en el segundo mapa de un grupo de 19 estudiantes cuyas características principales son que el concepto ***relación proporcional*** (o en su defecto el concepto ***proporción***) aparece diferenciado, poseen pocas relaciones incorrectas, no presentan secuencias lineales, en general los niveles jerárquicos están definidos y se sigue la lógica de la disciplina y en algunos casos existen también reconciliaciones entre algunas formas de expresión y los dos tipos de relación proporcional. Esta tendencia queda representada en la evolución de los mapas del estudiante I.M. (ver Figura 4 y Figura 5). Observamos que en el primer mapa ha utilizado 19 conceptos y en el mapa final ha utilizado los 25 conceptos, apreciándose que ha dado un nuevo significado al concepto ***razón***, así como al concepto ***proporción***. Se puede observar una clara diferenciación del concepto ***relación proporcional*** con todos los conceptos subsumidos perfectamente colocados, sin embargo, en este

mapa se ve que no se ha definido una relación entre los conceptos ***proporción*** y ***relación proporcional***, por lo que este estudiante no ha reconciliado ambos conceptos. Tampoco presenta relaciones transversales entre las diferentes formas de expresión de los dos tipos de proporcionalidad.

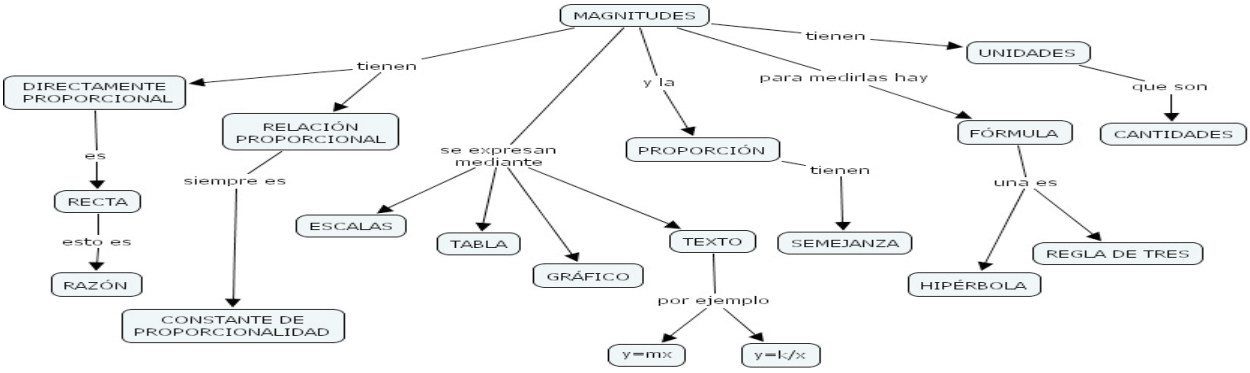


FIGURA 4. MAPA INICIAL DE I.M.

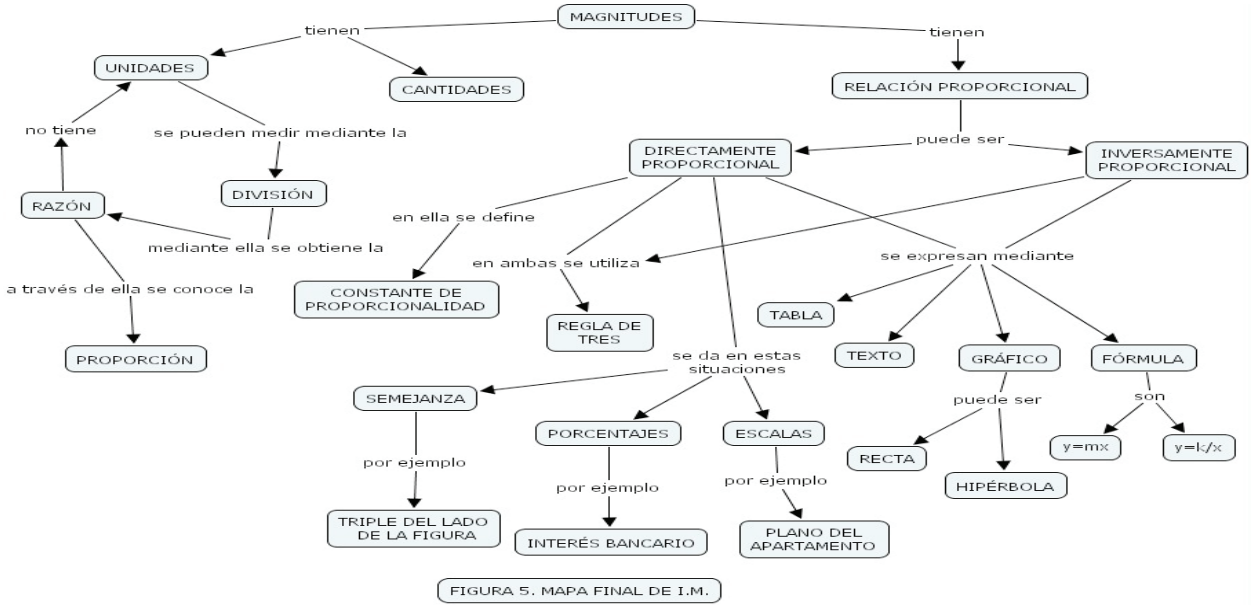


FIGURA 5. MAPA FINAL DE I.M.

Para terminar podemos hablar de un tercer grupo de 10 estudiantes, cuyos mapas finales presentan muchas características propias de un aprendizaje más memorístico y menos significativo, en donde no hay diferenciaciones y en pocos casos hay reconciliaciones, en general, en estos mapas la aparición de relaciones incorrectas es más frecuente y la lógica de la disciplina apenas se puede apreciar, apareciendo en algunos casos núcleos un tanto confusos. Fijándonos en los mapas del estudiante H.Z. (ver Figura 6 y Figura 7) podemos observar que aunque utiliza los 25 conceptos en el segundo mapa conceptual, de 24 relaciones definidas seis de ellas son incorrectas. Además, los conceptos no están colocados según su nivel jerárquico correspondiente, ni el mapa posee una estructura desde lo más inclusivo a lo más específico. Abundan las secuencias lineales y no existe ningún tipo de reconciliación, se pueden ver una serie de conceptos, en concreto, los que corresponden a las tres situaciones matemáticas que se han trabajado en el módulo como ejemplos de proporcionalidad directa, unidos arbitrariamente en niveles jerárquicos superiores y con unos enlaces con poco significado.

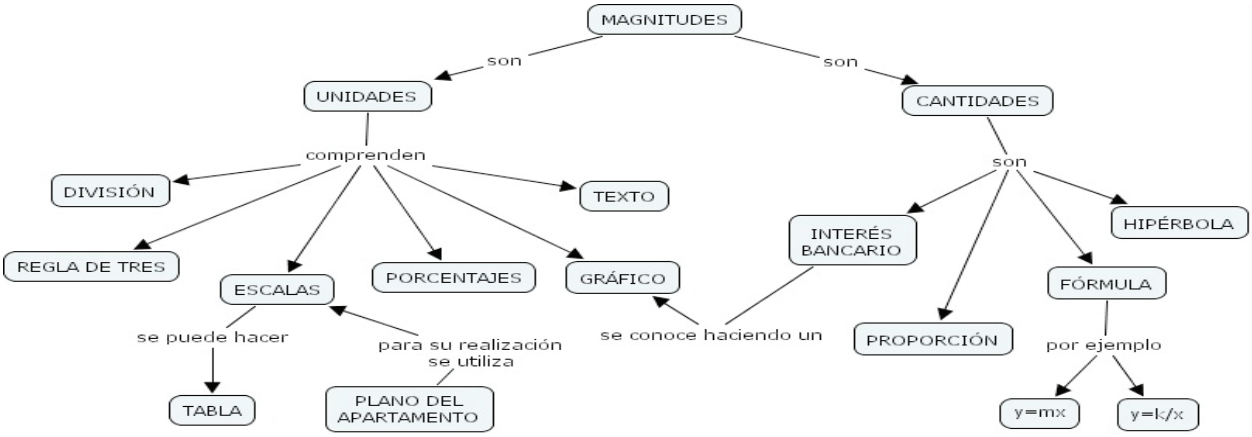


FIGURA 6. MAPA INICIAL DE H.Z.

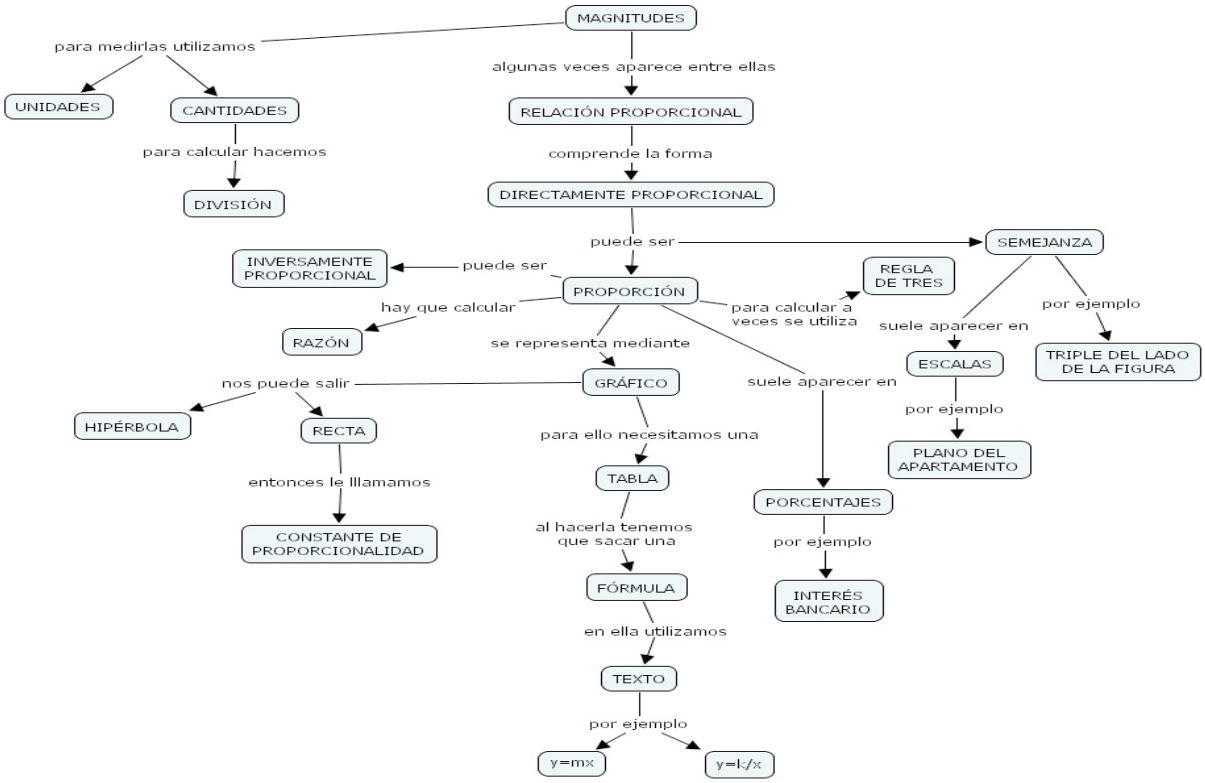


FIGURA 7. MAPA FINAL DE H.Z.

4 Conclusiones

Consideramos que los resultados obtenidos de la implementación del MI innovador en relación al tema de la proporcionalidad, han sido muy positivos en relación al logro de un aprendizaje escolar más significativo. Esta consideración se basa en los criterios para identificar los indicadores del AS en la valoración de los MMCC realizados por los estudiantes. Por ejemplo, la utilización de un número mayor de conceptos en la elaboración de los mapas posteriores a la instrucción, la disminución significativa de errores o proposiciones poco precisas, la mejora en la clarificación de los niveles de jerarquía y su coherencia con la naturaleza inclusiva de los conceptos, la disminución de cadenas lineales y núcleos confusos entre conceptos y el aumento de diferenciaciones progresivas

reconciliadas integradoramente, son todos ellos claros indicadores de un aprendizaje más significativo por parte de los estudiantes. También resulta evidente que los estudiantes han tenido serias dificultades a la hora de identificar los conceptos inclusivos más importantes, y por lo tanto, esto ha dificultado que se pudieran establecer diferenciaciones progresivas más enriquecedoras y reconciliadas. Sin embargo, en nuestra opinión es importante señalar que en un contexto escolar convencional, el hecho de implementar un MI fundamentado teóricamente ha posibilitado que un grupo de estudiantes haya tenido la oportunidad de aprender más significativamente en relación al tema de la proporcionalidad. Se han detectado asimismo tres patrones claros de mapas. Sería interesante identificar en futuras investigaciones la presencia de diferentes patrones de MMCC realizados por nuestros estudiantes. La definición operativa de los mismos y el establecimiento de correlaciones con calificaciones correspondientes a su rendimiento académico, así como con diferentes rasgos de su personalidad, actitudinales y de conducta, podrían convertir a esos MMCC en valiosos predictores del aprendizaje. A través de un AS, como ha quedado patente en nuestra investigación, se podrían modificar convenientemente los patrones de mapas originales, predictores de efectos no deseados, y conseguirse así mejores resultados en la educación integral (cognitiva, afectiva y psico-motora) de nuestros estudiantes.

5 Agradecimientos

La investigación referenciada se desarrolló en el marco del Proyecto GONCA, y fue posible gracias a la ayuda económica otorgada por el Depto. de Educación del Gobierno de Navarra (Resolución 294/2001, de 27 de Dic.).

6 Referencias bibliográficas

Afamasaga- Fuata'i, K. (2004). Concept Maps & Vee Diagrams as Tools for Learning New Mathematics Topics. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. of the 1st Int. Conf. on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra, pp.13-20.

Ausubel, D.P., Novak, J.D. y Hanesian, H. (1976). *Psicología educativa. Un punto de vista cognoscitivo*. México: Editorial Trillas.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. of the 1st Int. Con. on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Fiol, M.L. y Fortuny, J.M. (1990). *Proporcionalidad directa. La forma y el número.* Madrid: Editorial Síntesis.

Freudenthal, H. (1978). *Weeding and Sowing-Preface to a Science of Mathematical Education*. Dordrecht: D.Diedel.

González, F.M. (1997). Evidence of Rote Learning of Science by Spanish University Students. *School Science and Mathematics,* 97(8), pp.419-428.

Gonzalez, F.M. y Cañas, A. J. (2004). GONCA Project: Meaningful learning using CmapTools. *Advances in Technology-Based Education: Toward a Knowlegde-Based Society,* pp.747-750.

Guruceaga, A. y González, F.M. (2004). Aprendizaje significativo y Educación Ambiental: análisis de los resultados de una práctica fundamentada teóricamente. *Enseñanza de las Ciencias,* 22(1), pp.115-136.

Guzmán, M. de y Gil, D. (1993). *Enseñanza de las Ciencias y la Matemática.* Madrid: Editorial Popular S.A.

Novak, J.D. (1982). *Teoría y práctica de la educación.* Madrid: Alianza Editorial S.A.

Novak, J.D. (1988). Constructivismo humano: un consenso emergente. *Enseñanza de las Ciencias,* 6(3), pp.213-223.

Novak, J.D. (1998). *Conocimiento y aprendizaje.* Madrid: Alianza Editorial S.A.

Piaget, I. y Inhelder, B. (1972). *De la lógica del niño a la lógica del adolescente.* Buenos Aires: Paidós.

Rico, L. (2005). Competencias matemáticas e instrumentos de evaluación en el estudio PISA 2003. *PISA 2003.* Madrid: INECSE. Ministerio de Educación y Ciencia.

Serradó, A., Cardeñoso, J.M. y Azcárate, P. (2004). Los mapas conceptuales y el desarrollo profesional del docente. En: A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proc. of the 1st Int. Conf. on Concept Mapping,* Pamplona, España: Universidad Pública de Navarra, pp. 595-602.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

TWO STRATEGIES FOR ENCOURAGING FUNCTIONAL RELATIONSHIPS IN CONCEPT MAPS

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Abstract. Two strategies for encouraging formation of dynamic relationships in Concept Maps (CMaps) are discussed and tested, namely concept quantification and a dynamic focus question of the map. Two experiments were conducted to examine the effects of these two approaches on dynamic thinking during the CMap construction task. The first experiment examined the impact of the quantification of the root concept in the map. The second experiment explored the effect of the focus question of the map. For both experiments, the content of CMaps was assessed for the number of dynamic propositions and the number of quantified concepts. The results showed that the quantification of the root concept and the dynamic focus question "how" significantly increased dynamic thinking. In addition, the focus question affected the selection of concepts used in the maps and how those concepts were used. The studies, the theoretical background, and the implications of the findings are discussed.

1 Introduction

The fundamental component of a Concept Map (CMap) is a proposition, which consists of two concepts and their relationship (Novak 1998; Novak & Gowin, 1984). We have argued that dynamic thinking reflects a proposition that captures and represents a functional interdependency between two concepts. In contrast, a proposition that represents the relative position of the two concepts in the hierarchy of meaning constitutes static thinking (Safayeni, Derbentseva, & Cañas, 2005).

Given that dynamic thinking is an essential aspect of scientific reasoning, the question arises as to how it can be encouraged within the context of concept mapping. Earlier, we showed that Cyclic CMap (where concepts feed into one another in a closed loop) promoted dynamic thinking during a map construction task (Derbentseva, Safayeni, & Cañas, 2004). In this paper we demonstrate that there are additional two ways of creating situations where dynamic thinking is more likely to occur.

First, we set to retest the effect of root concept quantification on the dynamic nature of propositions in maps suggested by Safayeni et al. (2005) and initially tested by Derbentseva et al. (2004). The basic underlying idea was that if the root concept in a map was quantified, the probability of dynamic thinking would increase.

Second, we hypothesized that dynamic thinking can be encouraged, if the focus question of the CMap requires it, because the map is supposed to answer the focus question. The basic idea was that some questions are better answered by dynamic thinking, whereas other questions might require static thinking.

The body of research investigating CMaps is primarily focused on the tool's application in education and its usage in the knowledge management area. In educational setting, CMaps have been applied as knowledge organizers during learning of new material (e.g. Daley, 2004; Markow & Lonning, 1998; Edmondson, 1995; Hall, Dansereau, & Skaggs, 1992) and as an assessment tool for the evaluation of students' knowledge (e.g. Williams, 1998; 2003; Ali & Ismail, 2004) with some reservations (e.g., Ruiz-Primo, 2004, Ruiz-Primo & Shavelson, 1996).

The use of CMaps in capturing knowledge of experts was reported by Coffey, Eskridge & Sanchez (2004) and Ford et al. (1996). Coffey et al. (2003) reported on a performance support system based on CMaps. Hoffman, Coffey, Carnot, and Novak (2002) and Zanting, Verloop, and Vermunt (2003) have empirically demonstrated the effectiveness of using concept mapping as part of a methodology for eliciting expertise.

Most of the studies conducted on the subject of CMaps have been concerned with the practical application of the tool usually reporting positive results. This paper closely follows our previous work on examining CMap's capability of encouraging and representing functional interdependence among concepts. We experimentally demonstrate the validity of the root concept quantification approach to stimulating dynamic thinking in concept mapping that was theoretically suggested earlier (Safayeni et al., 2005) but had not been verified empirically.

Furthermore, the effects of an additional new strategy of changing the focus question of a map from "what" to "how" on dynamic thinking are empirically evaluated.

2 Theoretical Argument and Experimental Hypotheses

A CMap is a knowledge representation tool that is designed to identify and represent relationships between different concepts in a domain. Safayeni et al (2005) suggested that it is important for CMaps to be able to encourage and represent not only concepts' hierarchical interconnections or static relationships, but also their functional interdependencies or dynamic relationships. The static relationships between concepts help to describe, define, and organize knowledge for a given domain. Classifications and hierarchies are usually captured in relationships that have a static nature and indicate belongingness, composition, and categorization. The dynamic relationship between two concepts reflects and emphasizes the propagation of change in the concepts. It shows how change in *quantity*, *quality,* or *state* in one concept causes change in *quantity*, *quality,* or *state* of the other concept in a proposition.

Consider, for example, the relationship between the concepts "Concept Maps" and "Effective Teaching." A static relationship between these two concepts may be "CMap is a useful tool for effective teaching," and a dynamic relationship may be "Improvement in the quality of a CMap may lead to more effective teaching." Whereas the static relationship identifies the importance of CMaps for teaching, the dynamic relationship points to the interdependence among these concepts, particularly as they change. For a more elaborate discussion on static and dynamic relationships, see Safayeni et al. (2005).

Previous investigation has indicated that the vast majority of CMaps' propositions represent static rather than dynamic relationships (Safayeni et al. 2005). It is important to recognize that static conceptual relationships are for describing and organizing a significant part of our knowledge, and existing forms of CMaps are a useful tool for such representations. However, it is important to investigate how CMaps can be extended to represent dynamic relationships. Safayeni et al. (2005) presented a theoretical argument stating that enforcing a cyclic structure on CMaps and also quantifying the root concept in a map will encourage representation of functional relationships between concepts and stimulate dynamic thinking. Derbentseva et al. (2004) provided an empirical support for the effect of the cyclic structure; however the support for the effect of the root concept quantification was not found. Below, we report two experiments. The first one was designed to test the root concept quantification effect on dynamic thinking in concept mapping when quantification was made more explicit. The second experiment examined the effects of changing the focus question of the map on dynamic thinking.

2.1 Encouraging dynamic thinking: "Quantifying" the concepts.

Safayeni et al. (2005) suggested that quantification of the root concept in a map makes the concept more dynamic, and could lead to the construction of more dynamic propositions. Quantification of the root concept makes the concept significantly more specific and draws attention to the particular property of the concept that can change. Quantification of the root concept refers to adding a quantifier to the concept itself. For instance, concept "soil" might be quantified by adding a quantifier "quantity" or "quality," making the concept into "quantity of soil" or "quality of soil," as opposed to simply "soil." The addition of the quantifier sets the concept "in motion" and allows it to vary along the specified dimension. In other words, quantification of a concept makes the concept dynamic as opposed to a static category such as "soil."

Thinking about the root concept that is changing is anticipated to stimulate dynamic thinking and raise 'what-if' questions that will affect the selection of other concepts for the map. These concepts most likely will be selected on the basis of the degree to which they affect, or are affected by, the change in the property of the quantified root concept. The specific hypotheses tested in Experiment 1 are that (Hypothesis 1a) quantification of the root concept in the CMap will increase the quantification of the other concepts compared to the non-quantification condition, and (Hypothesis 1b) quantification of the root concept in the CMap will result in more dynamic propositions compared to the non-quantification condition. Derbentseva et al. (2004) attempted to test these two hypotheses and failed to experimentally demonstrate the effects. The difficulties that authors ran into were attributed to the ambiguity of the selected stimuli for their study. Thus, we made another attempt at testing these hypotheses with more specific and less ambiguous stimuli.

2.2 Encouraging dynamic thinking: Formulating a focus question.

When a CMap is constructed, it is done so with a particular purpose in mind. More precisely, the map is constructed for a certain audience, and to answer a specific question, called the focus question (Novak, 1998; Novak & Gowin, 1984). The focus question is a vital piece of information for any given map because it explicitly defines the question the map is designed to answer, as opposed to all possible questions. Nevertheless, focus questions are often omitted and are not recorded anywhere in the CMaps (A. J. Cañas, personal communication, July 15, 2004; J. D. Novak, personal communication, August 21, 2004).

Most maps seem to answer a question of "What is 'concept X'?" Such a question necessitates a description of concept X. The description of a concept mainly consists of identifying the concept's components or parts (e.g., plant has roots, stem, leaves, may have flowers, etc.), and by specifying the categories to which the concept belongs (e.g., plant is a living organism, or bear is a mammal). Uses or functions of the concept can also be specified in the process of describing the concept (e.g., plants are used as food and medicine), which would also place the concept in more specific categories (e.g., plants are food and drugs). Such a description is most likely to be static, because it identifies what the concept is, but not how the concept may change. That is, it is unlikely to include functional interrelationships among the concepts. However, if the question is posed differently, it might prompt dynamic thinking. Questions such as "What happens when the 'concept X' changes?", or "How does the 'concept X' work?" require one to think about change in the concepts and how they affect each other. That is, the focus question has a direct effect on the nature of the propositions in the map. We hypothesised that process-oriented focus questions will tend to be answered by reference to dynamic properties and interdependencies of the concepts. More specifically, the hypothesis tested in Experiment 2 (Hypothesis 2) is that the map constructed to answer the question "How does X work?" will tend to be more dynamic than the map that answers the question "What is X?"

3 Experiment 1

Experiment 1 was designed to test the effect of root concept quantification on the dynamic nature of constructed propositions and quantification of selected concepts.

3.1 Method

3.1.1 Subjects.

Seventy five undergraduate university students participated in the experiment. All subjects were enrolled in the same course and were offered a partial credit toward their course mark for their involvement in the study.

3.1.2 Stimuli selection

To allow for the comparison of the results to the non-quantification condition and to examine any inter-structural differences, the same structure prototypes as in Derbentseva et al. (2004) were used in Experiment 1 (Figure 1). Each structure prototype contained a root concept "As the number of plants increases," whereas all other boxes and arrows were left blank. Such root concept was selected to reduce the ambiguity in its meaning and make quantification more explicit. In the non-quantification condition the root concept in the structures was "plant."

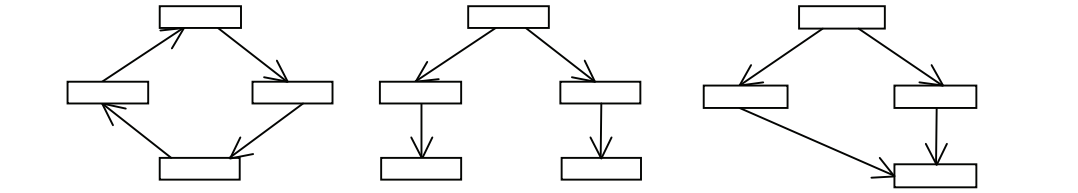


Figure 1: Prototypes of a) cyclic structure, b) hierarchical tree structure, and c) hierarchical cross-link structure

3.1.3 Procedure

The subjects were asked to fill out concepts and linking phrases in one of the three structure prototypes provided to them. There were three experimental conditions based on the three structure prototypes described in the stimulus section. Participants were assigned randomly to the conditions.

3.1.4 Measures

Each CMap constructed by the subjects was analyzed and assigned two different scores; (a) the concept quantification score, reflecting the percentage of quantified concepts in the map, and (b) the dynamic score, reflecting the percentage of dynamic propositions in the map.

The concept quantification score for a given map was assigned based on the percentage of quantified concepts in the map, excluding the root concept. The concept was considered quantified if a quantifier was added to the concept. For example, concepts such as "rate of plant maturation," "number of flowers," and "growth of more plants" were scored as quantified, but not the concepts such as "roots," "soil," and "leafs."

A dynamic score was computed for each map as a proportion of dynamic propositions in the map. Each map was analysed as a set of four independent propositions consisting of two concepts and a linking phrase between them. A list of 300 propositions was constructed. Each proposition was evaluated independently as to whether it reflected a dynamic relationship between the concepts. For example, a proposition "as the number of plats increases it leads to an increase in the process of photosynthesis" was classified as dynamic, and a proposition such as "plant has leafs" was classified as static.

3.2 Results and Discussion

The average scores for the two measures are presented in Table 1 for both, quantified condition (Experiment 1) and non-quantified condition (Derbentseva et al., 2004).

Condition for the root concept	Cyclic structure		Cross-Link structure		Tree structure	
	Concept Quant. Score	Dynamic score	Concept Quant. Score	Dynamic score	Concept Quant. Score	Dynamic score
Quantified	88.0%	93.5%	88.0%	95.0%	87.0%	92.0%
Non-Quantified	0.0%	45.4%	2.6%	21.1%	2.8%	13.54%

Table 1: Average values of the concept quantification and map dynamic scores for the three structure prototypes in both conditions.

Concept quantification scores and map dynamic scores of the quantification condition were compared to the concept quantification scores and map dynamic scores of the non-quantification condition between corresponding structures. The Wilcoxon-Mann-Whitney test results showed significant differences between quantified and non-quantified conditions of the same structure for all three structure prototypes and for both measures ($p < 0.001$).

The statistical analysis of the concept quantification scores provides strong support for Hypotheses 1a. For all three structure prototypes, the number of quantified concepts in maps dramatically increased in the quantification condition. The results of a Kruskal-Wallis test showed that there was no significant difference in the concept quantification scores among the three structures in the quantification condition ($\chi^2 = 0.06$, $p = 0.97$). This indicates that quantification of the root concept, regardless of the map's structure, significantly increases the likelihood of quantifying the other concepts in the map.

The statistical analysis of the dynamic scores provides strong support for Hypothesis 1b. The dynamic scores significantly increased in all three structure prototypes, compared to the non-quantification condition. Although significant differences in the dynamic scores between structures were observed in the non-quantification condition, there were no significant differences among the structures in the quantified conditions ($\chi^2 = 0.94$, $p = 0.95$). These results suggest that concept quantification can override structural differences, at least with respect to the proportion of dynamic propositions.

Although, the cyclic structure generated more dynamic propositions than the other two structures in the non-quantified condition, the tree and the cross-link structures with the quantified root concept produced significantly more dynamic propositions than the cyclic structure with the non-quantified root concept ($Z = -5.27$, $p < 0.001$ and $Z = -5.690$, $p < 0.001$ for the tree and the cross-link comparisons, respectively). The results of this experiment demonstrated that concept quantification is a very powerful technique for encouraging dynamic thinking in CMaps - more powerful than the cyclic structure alone.

4 Experiment 2

Experiment 2 was designed to examine the effect of the focus question on the content of CMaps, and to test the second hypothesis.

4.1 Method

4.1.1 Subjects

Eighty one undergraduate university students participated in the experiment. All subjects were enrolled in the same course and were offered a partial credit toward their course mark for their involvement in the study.

4.1.2 Stimuli selection

The stimulus for this experiment was a structure with six unconnected boxes arranged in a circle. Only the top box had a concept, "cars," written in it, and the remaining boxes were empty to be filled out and connected by subjects answering a given focus question. The stimulus is presented in Figure 2.

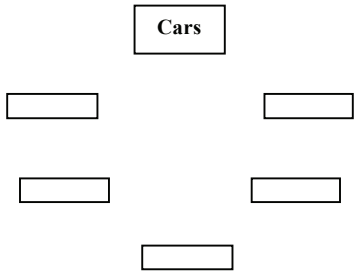


Figure 2: Stimulus used in experiment 2.

4.1.3 Procedure

The subjects were assigned randomly to the two conditions in this experiment - one for each focus question. The two focus questions were "What is a car?" and "How does a car work?" All other instructions and materials were the same for the two conditions. Participants were asked to answer one of the two focus questions by filling out the structure (Figure 2) with relevant concepts and linking phrases.

4.1.4 Measures

Similar to the first experiment, the maps were assigned the concept quantification scores and the map dynamic scores based, respectively, on the proportion of quantified concepts and the proportion of dynamic propositions in each map. The procedure for assigning the scores was the same as described in Experiment 1.

4.2 Results and Discussion

The maps in the "How" question condition generated significantly more dynamic propositions than the maps in the "what" question condition. The average map dynamic scores for the "What" and "How" question conditions were 21.0% and 55.0% respectively ($Z = -4.84$, $p < 0.001$). This result provided a strong support for Hypothesis 2.

There were no significant differences for the concept quantification scores of the two conditions. The average concept quantification scores for the "What" and "How" question conditions were 2.5% (STD = 0.08) and 1.0% (STD = 0.04) respectively (Z = -0.89, p = 0.37). That is, the focus question influenced the dynamic score of the map, but had little impact on the quantification of the concepts.

Comparison of the data of Experiment 2 with the non-quantified condition from Table 1 showed that the dynamic question "how" condition and the cyclic structure with no quantification produced similar results on both measures. That is, the cyclic map structure and the dynamic focus question made the relationships between concepts more dynamic, but did not quantify the concepts.

Furthermore, the dynamic focus question condition resulted in more dynamic maps than either the cross-link or the tree structures in the non-quantified condition. This effect is particularly interesting because it emphasizes the significance of the focus question. One may think of the two structures, the tree and the cross-link, as representing the "usual" way of concept mapping, which resulted in minimal dynamic thinking. In contrast, posing the dynamic question "how," without any structural constraints, significantly increased the number of dynamic propositions.

4.2.1 Additional findings

The root concept "Cars" was used significantly more often in propositions in the "What" question condition (average of 59.5%) than in the "How" question condition (average of 44.5%). The frequency of usage of the concept "Cars" in the two experimental conditions indicates that the root concept was more central in answering the "What" question rather than the "How" question (Z = -2.99, p = 0.003). Fairly low proportion of propositions starting with the root concept were dynamic (13% in the "What" maps and 18% in the "How" maps) with no significant difference between the two conditions (Z = -0.877, p = 0.381). However, 81% of the propositions that ended with the root concept were dynamic in the "How" maps, while only 17% of such propositions were dynamic in the "What" maps. It is also worth noting that in the "How" question condition propositions ended with the root concept significantly more often than in the "What" question condition (Z = -2.863, p = 0.004) which might be an indication of "How" maps being less hierarchical (with more "up-flows") than "What" maps.

Analysis of the concepts from the maps in the two conditions revealed that the sets of concepts differed to some extent. Table 2 summarizes the observed frequencies of some of the concepts for each of the two conditions.

Concepts unique to one of the conditions	% of maps in "How" question condition	% of maps in "What" question condition	Concepts used in both conditions	% of maps in "How" question condition	% of maps in "What" question condition
Transportation	0%	50%	People	2%	30%
Keys	37%	0%	Steering	27%	5%
Shape/color	0%	28%	Energy	83%	35%
Travel	0%	25%	Engine	73%	50%
Ignition	20%	0%	Wheels	37%	40%

Table 2: Frequency of concepts in the maps of the two conditions in Experiment 2

Table 2 shows that some concepts were unique to only one condition (e.g. "transportation" and "keys") while other concept were used in both conditions, some with different frequencies (e.g. "people" and "energy") and others with relatively similar frequencies (e.g. "wheels" and "engine").The differences can only be explained by the difference in the focus questions, because everything else was the same The data in Table 2 suggest that some concepts were more appropriate to answer one question than the other. For example, to answer the question "What is a car?", it would seem reasonable to place the concept "car" into a super-ordinate category of "transportation," whereas to answer the question "How does a car work?", a reference to a category of "transportation" is not helpful. The concept "wheels" is particularly interesting case since it appeared with fairly same frequency in both conditions; there was no difference in the number of propositions constructed with this concept between the conditions (Z = -0.385, p = 0.707). Similarly, there was no difference in the location of this concept in the propositions (i.e. being in the beginning of a proposition (Z = -0.106, p = 0.935) or in the end of a proposition (Z = -0.084, p = 0.935)).

However, the propositions constructed with the concept "wheels" were significantly more often dynamic in the "How" question condition than in the "What" question condition ($Z = -3.416$, $p = 0.001$). This analysis suggests that even when the same concept with the same frequency is used to answer a different focus question, it is used differently. A typical proposition with the concept "wheels" in a "What" question map was "Cars have wheels," and in a "How" question map "Wheels move cars." Needless to say that concepts with different frequencies are also used differently, that is, constructing more dynamic propositions in the "How" condition.

The difference in the selection of concepts and their meanings depending on the question to be answered might seem intuitively obvious; however, the focus question in concept mapping has often been omitted or unintentionally replaced with a "what" type question. Given the important role of the focus question in the selection of concepts, the concept mapping community should pay much more attention to the focus question. It is worth pointing out that Novak and Gowin (1984) recognized the importance of the focus question, and thus, one may wonder why the focus question has so often been ignored.

5 Conclusion

The research in this paper was based on the premise that knowledge can be viewed as having both a dynamic and a static components. The typical applications of CMaps have concentrated on the static dimension. Although, the static representation provides a useful means of organizing knowledge and noting significant relationships, both static and dynamic relationships are necessary for adequate representation of knowledge.

Two experiments were designed to test the effects of root concept quantification and formulation of a dynamic focus question on dynamic thinking and representation in CMaps.

A comparison of the results from the two experiments reported here and that reported by Derbentseva et al. (2004) suggests that both the cyclic map structure and the focus question "how" increase the number of dynamic propositions without increasing the concept quantification score. On the other hand, the concept quantification condition provided the strongest effect not only on concept quantification scores, but also on the number of dynamic propositions. For both scores, this effect was stronger than the cyclic structure with no quantification, or the dynamic focus question "how." One possible explanation of this effect is that concept quantification acts as a constraint on an individual and forces them to construct dynamic propositions with another quantified concept. This constraint is so powerful that it is hard to imagine how a proposition can be completed without making it dynamic.

The quantification of the root concept in Experiment 1 is an extreme version of the idea of concept quantification. The concept was not only quantified, but it was set in motion: a dimension was specified ("number of plants") and the direction of change was indicated ("as the number of plants increases"). It is worth pointing out that, studies reported by Derbentseva et al. (2004) that only quantified the concept, without setting it in motion, did not produce any effect. The extent of concept quantification is an area that merits further investigation.

The results of the reported studies should be treated with caution. This is primarily because the measure of the dynamic score of a map was based on scoring each proposition independently, and thus other properties of the map were not captured. CMaps most likely have other properties related to dynamic thinking that were not picked up by our measures.

There are several practical implications from this study. First, there are, at least, three ways in which dynamic thinking can be encouraged. Second, concept quantification may be the most robust way of encouraging dynamic thinking. Third, the practitioner should pay close attention to the focus question; it not only influences the selection of the concepts, but also their relationship to each other. Still, more research is needed to improve the dynamic measure of a map as a system, and to develop an overall measure of the degree of unity and interdependence of concepts in a CMap.

References

Ali, M. & Ismail, Z. (2004). Assessing student teachers' understanding of the biology syllabus through concept mapping. In A.J. Cañas, J.D. Novak, & F.M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology* (pp. 53-58). Pamplona, Spain: Universidad Pública de Navarra.

Coffey, J. W., Cañas, A. J., Reichherzer, T., Hill, G., Suri, N., Carff, R., Mitrovich, T., & Eberle, D. (2003). Knowledge modeling and the creation of El-Tech: A performance support system for electronic technicians. *Expert Systems with Applications, 25*(4).

Coffey, J. W., Eskridge, T. C. & Sanchez, D. P. (2004). A case study in knowledge elicitation for institutional memory preservation using concept maps. In A.J. Cañas, J.D. Novak, & F.M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology* (pp. 151-157). Pamplona, Spain: Universidad Pública de Navarra.

Daley, B. J. (2004). Using concept maps with adult students in higher education. In A.J. Cañas, J.D. Novak, & F.M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology* (pp. 183–190). Pamplona, Spain: Universidad Pública de Navarra.

Derbentseva, N., Safayeni, F., & Cañas, A. J. (2004). Experiments on the effect of map structure and concept quantification during concept map construction. In A.J. Cañas, J.D. Novak, & F.M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology* (pp. 125–134). Pamplona, Spain: Universidad Pública de Navarra.

Edmondson, K. M. (1995). Concept mapping for the development of medical curricula. *Journal of Research in Science Teaching, 32,* 777-793.

Ford, K. M., Coffey, J. W., Cañas, A. J., Andrews, E. J., & Turne, C. W. (1996). Diagnosis and explanation by a nuclear cardiology expert system. *International Journal of Expert Systems, 9,* 499-506.

Hall, R., Dansereau, D., & Skaggs, L. (1992). Knowledge maps and the presentation of related information domains. *Journal of Experimental Education, 61,* 5-18.

Hoffman, R. R., Coffey, J. W., Carnot, M. J., & Novak, J. D. (2002). *An empirical comparison of methods for eliciting and modeling expert knowledge*. Paper presented at the Meeting of the Human Factors and Ergonomics Society, Baltimore MD.

Markow, P. G., & Lonning, R. A. (1998). Usefulness of concept maps in college chemistry laboratories: Students' perceptions and effects on achievement. *Journal of Research in Science Teaching, 35,* 1015-1029.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept Maps(R) as facilitative tools in schools and corporations*. Mahwah, NJ: Erlbaum.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* New York, Cambridge University Press.

Ruiz-Primo, M. A. (2004). Examining concept maps as an assessment tool. In A.J. Cañas, J.D. Novak, & F.M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Vol. 1. Concept Maps: Theory, methodology, technology* (pp. 555–562). Pamplona, Spain: Universidad Pública de Navarra.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33,* 569-600.

Safayeni, F., Derbentseva, N., & Cañas, A. J. (2005). A theoretical note on concepts and the need for cyclic concept maps. *Journal of Research in Science Teaching, 42*(7), 741 - 766.

Williams, C. G. (1998). Using concept maps to assess conceptual knowledge of function. *Journal of Research in Mathematical Education, 29,* 414-421.

Zanting, A., Verloop, N., & Vermunt, J. D. (2003). Using interviews and concept maps to access mentor teachers' practical knowledge. *Higher Education, 46,* 195-214.

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USING CONCEPT MAPPING IN THE DEVELOPMENT OF THE CONCEPT OF POSITIONAL SYSTEM

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Abstract. Psychologists such as Vygotsky and Skemp indicate that as a superordinate concept the understanding of positional system requires knowledge of several bases for its adequate development. However, current elementary mathematics curricula fail to adequately develop the concept of positional system, attempting instead to teach operations in base ten in isolation. This paper exhibits the power of concept mapping to reveal to teachers the centrality of this concept in elementary mathematics. The map presented here, constructed by Meridith, a pre-service teacher, also features the pedagogical content knowledge required to successfully teach the concept of positional system and the other mathematics concepts to which it is related. Meridith's pedagogical treatment is neither simplistic nor reductionist, but reveals the conceptual essence of the concepts in question and the complexity of their relationships within elementary mathematics when taught as a conceptual system.

1 Introduction

The teaching of multiple bases to develop the concept of positional system that figured so prominently in the US mathematics education reform during the 1960s and 1970s was swept out of favor with the advent of the back to basics movement that succeeded the "new math" era. Unfortunately, its former prominence in the elementary mathematics curriculum has yet to be restored. It is not included in the current reform effort of the National Council of Teachers of Mathematics (NCTM, 1989, 2000), and is absent from most elementary school mathematics and elementary mathematics methods textbooks as well (cf. Burris, 2005, for a notable exception). The multi-base blocks invented by Zoltan Dienes some fifty years ago have virtually disappeared not only from US classrooms but from the catalogs of suppliers of mathematics manipulatives as well (the Prairie Rainbow Blocks developed by George Gagnon constitute a rare exception). Only base ten blocks are in common use in US classrooms. And yet not only Dienes, but Skemp (1987) and Vygotsky (1962) stressed the importance of teaching multiple basic level concepts for the formation of a superordinate concept such as positional system.

> As long as the child operates with the decimal system without having become conscious of it as such, he has not mastered the system but is, on the contrary, bound by it. When he becomes able to view it as a particular instance of the wider concept of a scale of notation, he can operate deliberately with this or any other numerical system. The ability to shift at will from one system to another…is the criterion of this new level of consciousness, because it indicates the existence of a general concept of a system of numeration (Vygotsky, 1962, p. 115).

Skemp (1987) stresses that a superordinate concept can not be developed in the mind on the basis of a single basic level concept. At least several basic level concepts are required. A concept of positional system can not be developed through the teaching of base ten alone. And Vygotsky (1962) asserts that a child can not master the decimal system without attaining a mastery of the more general concept of positional system. Thus, as these leading psychologists in the theory of learning attest, one can not understand base ten without learning other bases as well.

2 Developing the Concept of a Positional System in Teacher Education

Not only is the knowledge of multiple bases essential for understanding the concept of a positional system, but the concept itself provides a conceptual foundation for the four fundamental operations on whole numbers and for the development of the concept of variable, exponent, polynomial and polynomial operations, decimals, fractions, and area and volume experienced through the geometric modeling of positional systems. Consequently, the omission of this important means to concept development has multiple consequences for the learning of mathematics beyond the elementary level.

While the case for teaching multiple bases has been well documented in the psychological literature (Vygotsky, 1962; Skemp, 1987), its omission from elementary school mathematics textbooks presents difficulties for prospective and practicing teachers who may acknowledge its importance but be inclined to protest that "it's not in

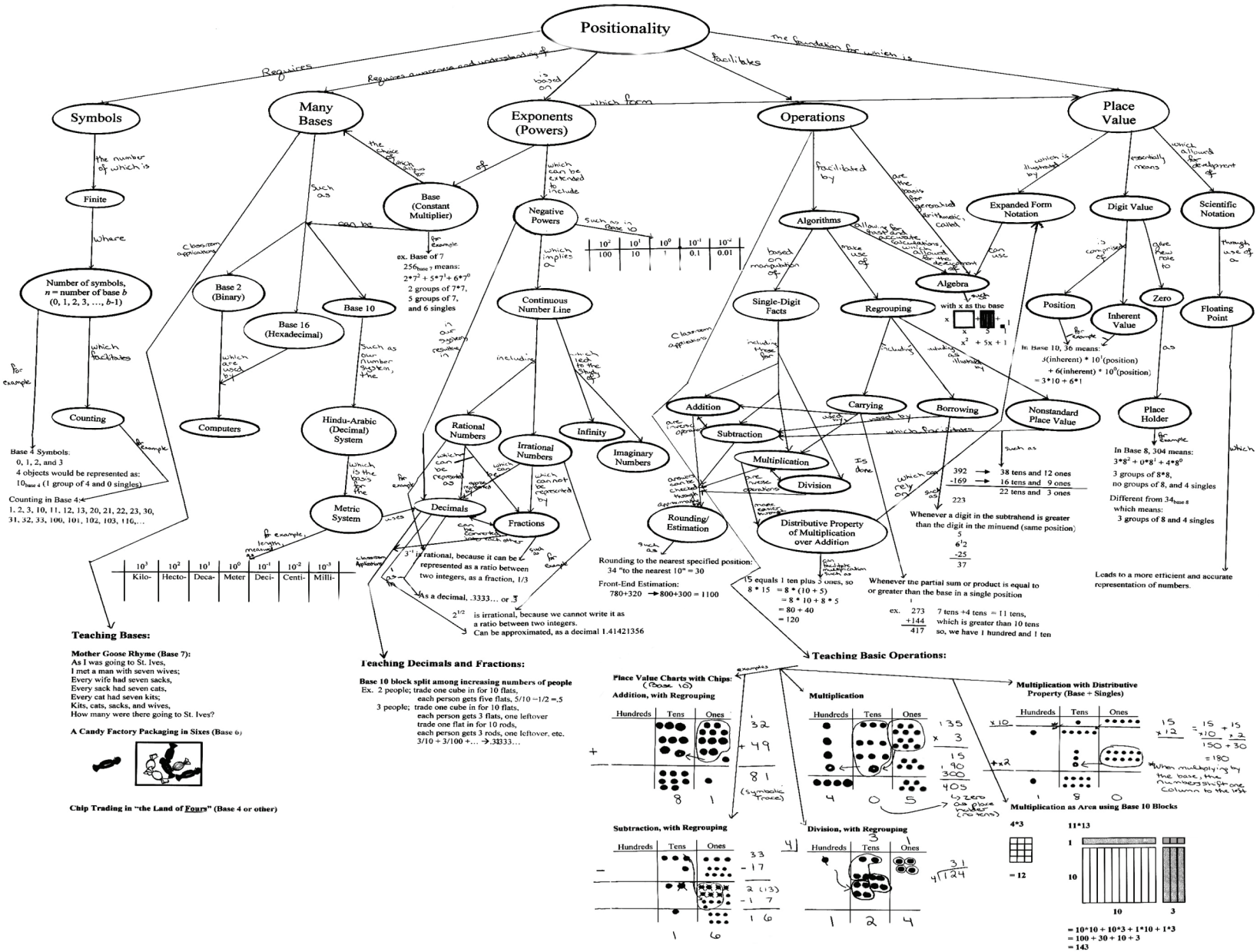


Figure 1. Meridith's concept map.

the curriculum". Assigning pre-service and in-service teachers the task of constructing a concept map exploring the connections of the concept of positional system to other important mathematical concepts, reveals the centrality of this concept both in elementary mathematics and as a foundation for concepts encountered at the middle school level and beyond. The concept map shown in Figure 1 was made by a pre-service teacher in response to such an assignment. When the concept of positionality was addressed in her elementary mathematics methods course, concept mapping was also introduced, and students were asked to begin to draw a map centered on the role of positionality in school mathematics. As additional mathematics concepts were explored, students were encouraged to continue adding to their maps, so that the construction of the concept map became a project that continued to develop over the semester. The assignment revealed to students the multiple connections the concept of positional system has with mathematics concepts that children will study in the later elementary and middle school years and even beyond. These include such concepts as decimals, exponentials, area, volume, and polynomials and their operations.

3 Meridith's Map

Figure 1 presents a view of Meridith's concept map in its entirety. Figure 2 focuses on the extreme left section of the map, which reveals her understanding of the need to establish the concept of positional system on the foundation of multiple bases. Under the designation "Symbols" we see that she understands that for any base b, numerals from 0 through 1, 2, 3, …, b-1 are necessary to designate the numbers in the system. Base 4 is provided as an example, with 0, 1, 2, and 3 as numerical symbols, and counting in base 4 is illustrated.

Moving to the right across the map (Figure 2), Meridith further develops these ideas, beginning with the initial proposition that the concept of "positionality requires awareness and understanding of many bases", including base 2 and 16 used in computers, and base ten employed in both the metric and Hindu Arabic numeration systems. Her illustrations of the powers of ten designated in the metric system and the powers of 7 in the expanded form of the number $256_{\text{base } 7}$ show the link to exponentiation that derives from a consideration of meaning of numbers across systems employing diverse bases.

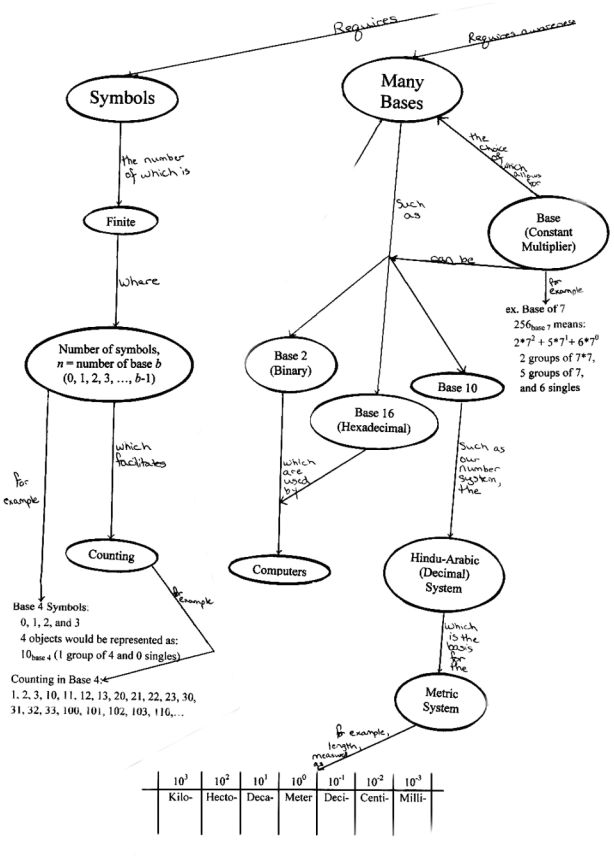


Figure 2. Left side of the Meridith's concept map showing "Symbols" and "Many Bases" as subsumed concepts.

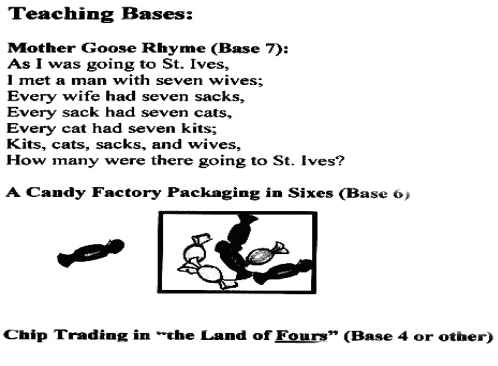


Figure 3. Classroom applications involving bases.

Figure 3 identifies the section of Meridith's concept map that includes three classroom applications involving different bases. A Mother Goose rhyme in base 7, a packaging example in base 6, and chip trading in base 4, are examples of methods that can be used with elementary students to develop the concept of positional system from the study of multiple bases. Pre-service teachers were encouraged to include pedagogical methods (and these are found throughout Meridith's map), as exemplary pedagogical practices that embody important conceptual content.

Chip trading in base 4 is treated in Burris' (2005) text for elementary teachers *Understanding the Math You Teach*, a feature that renders this text unique. The use of chip trading to teach the fundamental operations of addition, subtraction, multiplication, and division appears in the bottom right section of Meridith's concept map, denoted as "Teaching Basic Operations" (see Figure 1). This section is specifically highlighted in Figure 6 and represents a pedagogical approach that connects the algorithmic operations with their conceptual genesis.

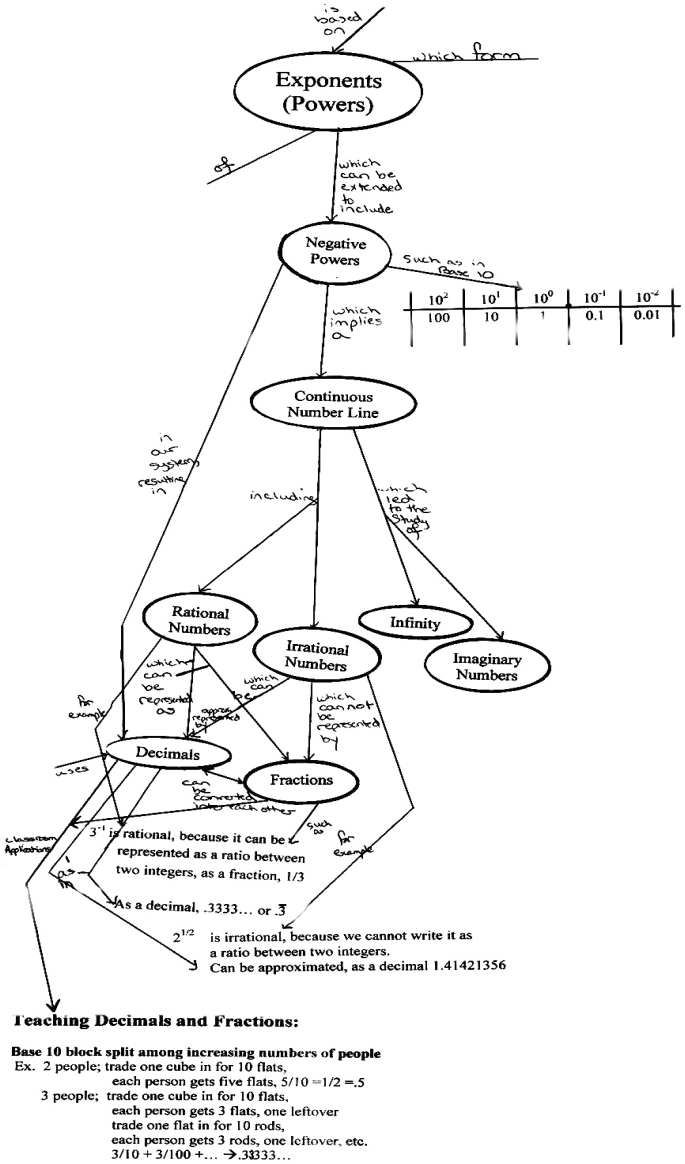


Figure 4. Center of Meridith's concept map showing "Exponents" as a related concept.

Considerations of exponentiation are shown in Figure 4, including the extension to negative integer and fractional powers, which designate fractional and irrational numbers, respectively, and to their repeating (rational) and infinite non-repeating (irrational) decimal representations. Meridith goes further to relate to the real number line the combined infinite set of all numbers capable of being expressed as a base raised to an integer or fractional power, and illustrates the generating of terminating and repeating decimals from partitive division using base ten blocks, an effective teaching strategy.

Figure 5 shows the interrelationships among the four fundamental operations of addition, subtraction, multiplication, and division of whole numbers, together with attendant processes of regrouping as required. Embedded within Figure 5 is an important link between the standard algorithms for these processes and modeling of similar operations with polynomials. The standard algorithms are unfortunately downplayed in the current reform movement (NCTM, 1998) but are, as Meridith's map reveals, fully conceptual. She illustrates the ease of transition to algebra from a consideration of multiple bases, as it is an easy step from the notion of a variable base b, where b can be any integer greater than 1, to the variable x which can be any real number. One simply removes the positive integer restriction to produce a real valued variable. Further, the familiar expanded form for numbers in various bases (such as $304_{\text{base } 8}$ shown here and $256_{\text{base } 7}$ in Figure 3) is isomorphic to the form in which a polynomial (such as $x^2 + 5x + 1$) must of necessity be written, since the value of x is unknown and hence, its terms cannot be added together. Meridith uses an area model for the polynomial. In addition, she integrates both estimation by rounding and scientific notation into this section of the map.

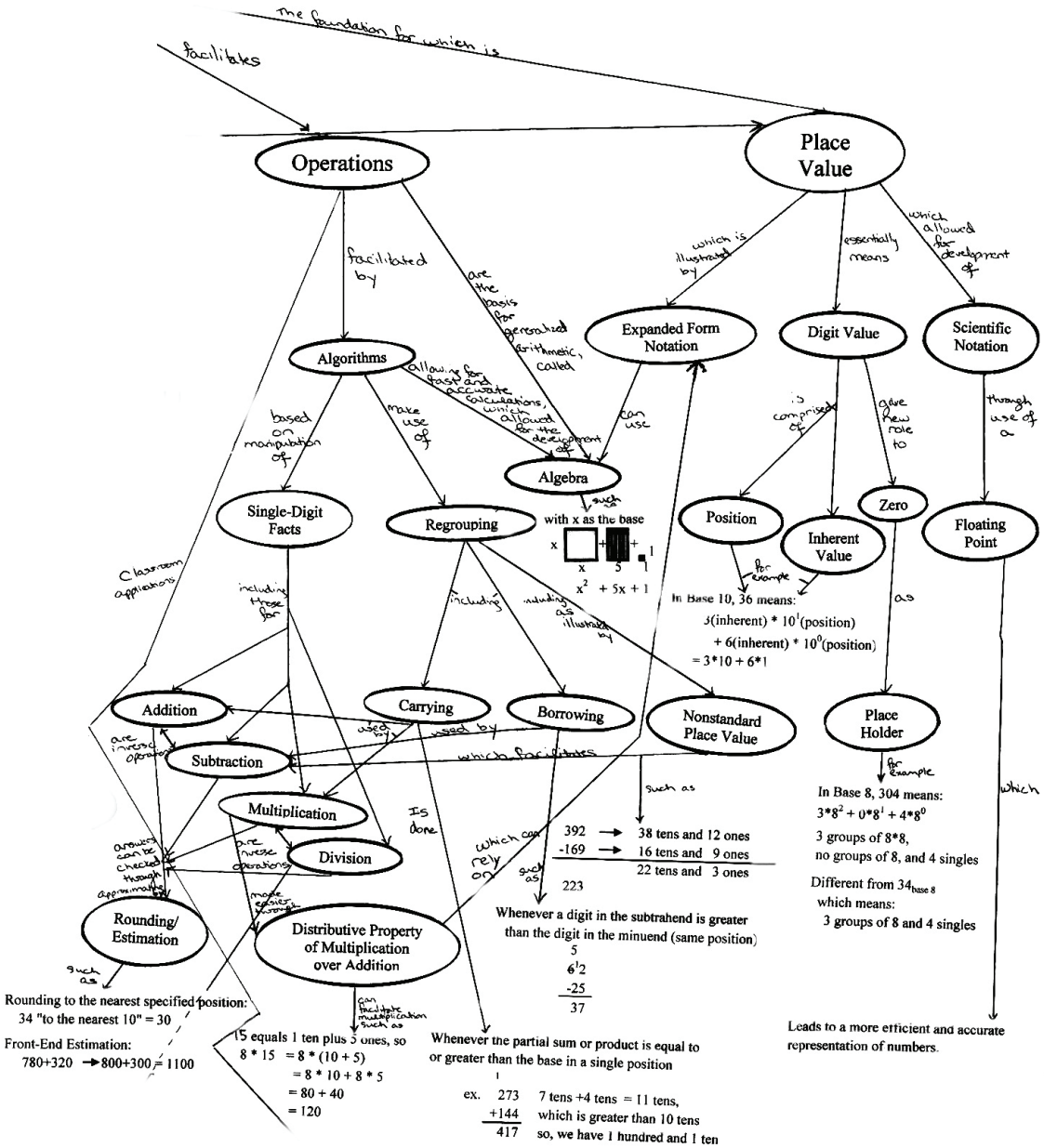


Figure 5. Right side of Meridith's concept map showing "Operations" and "Place Value" as subsumed concepts.

In Figure 6, Meridith reveals the pedagogical content knowledge necessary for proper instruction in positionality employing chip trading (Davidson, Galton, & Fair, 1975) with the requisite trades for regrouping as required in performing the four fundamental multi-digit operations on integers. She also employs an area model for multiplication. It is noteworthy that the conceptual and the algorithmic are connected without a separation of "concepts" and "procedures".

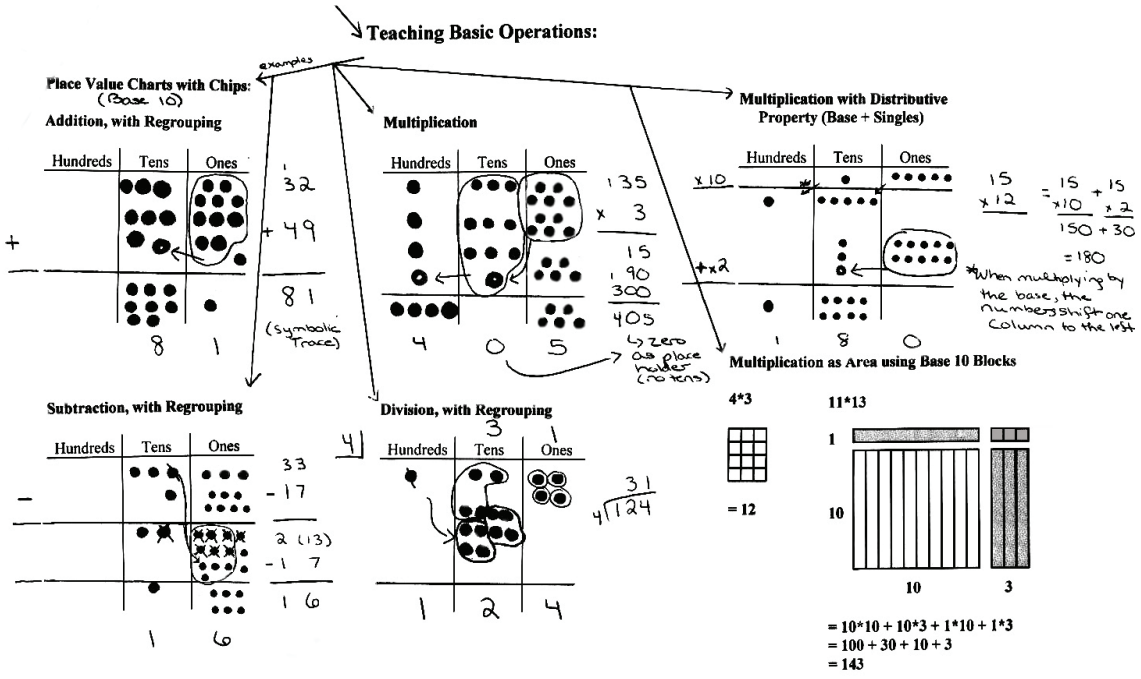


Figure 6. Meridith's pedagogical approach connecting the algorithmic with the conceptual.

Under "Teaching Basic Operations" the use of chip trading as a pedagogical tool is displayed. In the "Addition with Regrouping" model, Meridith illustrates the removal of ten "ones" chips and their trade for a "ten" chip in adding 32 + 49 = 81. In the "Subtraction with Regrouping" model, she shows the manner in which a "ten" chip is traded for ten "ones" chips, and then 7 "ones" chips are removed from the resulting 13 "ones" chips. Then one "ten" chip is removed from the remaining two "tens" chips in the subtraction problem 33 -17 = 16.

In the depiction of multiplication using chip trading, Meridith solves the problem 135 x 3 = 405 by tripling the 5 "ones" chips and trading ten of the resulting 15 chips for a "ten" chip, then tripling the 3 "tens" chips and trading the resulting 9 +1 "tens" chips for a single "hundred" chip. Tripling the original "hundred" chip and adding this additional "hundred" chip results in the solution of 4 "hundreds", no "tens" and 5 "ones" chips. She then shows how in multiplying 15 x 12, the 12 is first split into 10 + 2, then each addend separately multiplies 15, and finally the resulting partial products are added to obtain 180. The distributive property is the underlying conceptual mechanism here, and this is emphasized in the area model for multiplication of 13 x 11.

Finally, Meridith illustrates the use of chip trading in the division of 124 by 4. First the "hundred" chip is traded for 10 "tens" chips to provide 12 "tens" chips. Twelve tens divided by 4 is 3 tens, and finally four "ones" divided by four is 1 "one". Therefore the quotient is 31 which is 3 tens and 1 unit.

The power of chip trading is that it requires the child to employ the same cognitive processes that are required for computing efficiently with multi-digit numbers in our base ten positional system. As these processes are

employed, the conceptual content of the algorithms is continually reinforced; they are not arbitrary "rules" to be memorized and executed by rote, but meaningful processes that rely for their power on the concept of positional system and the properties of actions such as the distributive property of multiplication over addition. Eventually, children have no need for the chips and simply invoke the representation of the trades. Finally, they are able to perform the requisite mathematical actions on the numbers alone, and to see that the algorithms are merely the symbolic trace of the meaningful mathematical actions they formerly performed on objects. When they attain this level of competence and understanding they will not find actions on large numbers (which would be too cumbersome to be easily performed with objects) to be daunting, nor will they need a calculator to perform them.

Meridith's map thus shows connections of the concept of positional system with its genesis from a consideration of multiple bases (perhaps begun with simple nursery rhymes, and pictures for young children as shown in Figure 3), through connections with exponentiation, decimals, fractions, the real number line, estimation and rounding, the metric system and scientific notation so important for measurement, area models, the concept of variable, and the operations of addition, subtraction, multiplication, and division of both integers and polynomials.

4 "Death by Decimal"

Concept mapping reveals the centrality of the concept of positional system in the conceptually dense system of concepts that comprise elementary school mathematics. Not only does it connect to many important concepts that students will study concurrently or for which it will prepare them for study in the future, it is also a prerequisite for any real understanding of the base ten system. And the consequences of failure to adequately grasp this concept in real world applications range from measurement inaccuracies in trades such as construction to those in professions such as medicine. The first can be costly; the second deadly.

In her study of the mathematical errors of student nurses, Pirie (1987) documents the extent to which student nurses fail to correctly use mathematics to make mindful decisions in such tasks as unit conversions, dosage calculations, and fluid monitoring. Fragile and/or incorrect conceptual development in mathematics often invites the use of procedural shortcuts that increase the potential for error and the possibility of disastrous results for a patient whose life may depend on the correctness of the calculation. In the absence of fundamental conceptual grounding, the same mathematical procedures that could be used to promote the health and well-being of a patient become unreliable.

The severity of miscalculation is evident in the simulation study published in the *American Journal of the Diseases of Children*. Perlstein et al., whose study involved the staff of a neonatal intensive care unit working with simulated physicians' orders, reported that "56% of the errors tabulated would have resulted in administered doses ten times greater or less than the ordered dose" (sited in Pirie, 1987, p.145.) Lesar (2003) studied and classified the 200 tenfold errors in medication dosing that occurred in an 18 month period at a 631-bed teaching hospital citing such errors as a misplaced decimal point, adding an extra zero, or omitting a necessary zero. Przybycien (2005, p. 32) reports that a physician ordered morphine .5 mg IV for a 9-month-old baby but because of a missed decimal an inexperienced nurse gave the baby 5 mg of morphine IV, and the baby died. It is an example of "death by decimal" and the lack of meaningful understanding of positionality continues to lead to such tragedy.

5 Summary

Using concept mapping in the development of the concept of positional system substantively reveals the need to teach multiple basic level concepts for the formation of a superordinate concept. Meridith's carefully considered concept map of positionality is in sharp contrast to the superficial treatment often found in popular mathematics texts which display a decimal number with digits to the right and left of the decimal point labeled to indicate the name and relative value of each position. Meridith's concept map clearly indicates what must be taught to students for a meaningful understanding of positionality to develop. It reflects her in-depth exploration of the meanings associated with and underlying the concept of positional system, its antecedent concepts, and the complexity of their interrelationships within a conceptual system. The map addresses a serious deficiency in current elementary mathematics programs and provides a reliable direction for future mathematics curriculum development. The inadequate development of positional system inhibits future learning in mathematics and has important

consequences for societal applications that require knowledge of the decimal system. Research in the field of medicine corroborates the number of deadly errors attributable to misplaced decimals in fluid monitoring and drug dosage calculations. It would be difficult to imagine a nursing student who understands the concepts and relationships depicted in Meridith's map ever making the devastating errors chronicled in Pirie's (1987) and Przybycien's (2005) research.

6 Acknowledgement

Our special thanks to Meridith Jackson who graciously provided the clinical content of the study reported in this paper.

References

Burris, A. (2005). *Understanding the math you teach.* Prentice Hall: Upper Saddle River, NJ.

Davidson, P.S., Galton, G.K., & Fair, A.W. (1975). *Chip trading activities.* Fort Collins, CO: Scott Resources.

Lesar, T.S. (2003). Tenfold medication dose prescribing errors. *The American Journal for Nurse Practictioners, 7*(2), 31-32, 34-38, 43.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics (1998). *The teaching and learning of algorithms in school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Pirie, S. (1987). *Nurses and mathematics: Deficiences in basic mathematical skills among nurses.* London: Royal College of Nursing.

Prairie Rainbow Blocks, Prairie Rainbow Company. Oakland: CA.

Przybycien, P. (2005). *Safe meds: An interactive guide to safe medication practice.* St. Louis: Elsevier Mosby.

Skemp, R. (1987). *The psychology of learning mathematics*. Mahwah, NJ: Lawrence Erlbaum.

Vygotsky, L.S. (1962). *Thought and language.* Cambridge, MA: MIT Press.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006,

USING CONCEPT MAPPING TO FACILITATE METACOGNITIVE CONTROL IN PRESCHOOL CHILDREN

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Abstract. The purpose of this study was to explore the ways in which a concept mapping task could enhance the learning experience of preschool children by facilitating metacognitive skills involving planning, prediction, correcting errors and evaluating progress. Specifically, this study used discourse analysis from transcribed videotapes to explore child-adult interactions in three small groups as each group engaged in building a concept map about pumpkins. The targeted observations specifically focused on (1) identifying scaffolding of metacognitive control by adults during the activity and (2) seeking evidence of regulation-in-action evidenced by children's talk and behavior. Findings suggest that the extent to which preschoolers are able to engage in metacognitive processes depends on the manner in which the activity is framed and structured by the adult overseeing the activity, highlighting the importance of the social context in fostering the effective use of "metacognitive tools."

1 Introduction

Concept maps have been described as "metacognitive tools" (Mintzes, Wandersee & Novak, 1997) that encourage students to think reflectively about what they know through the visual representation of concept meanings and relationships. The process of creating and modifying a concept map involves making decisions about the different ways concepts are related to one another, leading the individual to reflect on prior knowledge as it relates to new material (McAleese, 1998), as well as engaging in "control" processes of planning, monitoring progress, and evaluating goal attainment as the map is constructed (Brown, 1987). Metacognitive processes, enabling the learner to flexibly and selectively coordinate knowledge, lead to a deeper level of understanding by making students responsible for their own learning (Georghiades, 2000).

Improvements in self-reflection and strategic action following concept mapping instruction have been reported by students in college (August-Brady, 2005), high school (Chularut & DeBacker, 2004), and primary school (Stow, 1997). Figueiredo, Lopes, Firmino and Sousa (2004) demonstrated that some preschool children are able to recognize a concept map as a scheme that helps them "know what they know." Beyond this, however, research has not considered whether concept mapping activities can facilitate young children's metacognitive control. It is known that during problem-solving activities, preschoolers are able to exhibit "regulation in action" by stating goals, planning, "thinking aloud," and detecting and correcting their own mistakes (Cox, 1994). Hence, preschoolers' talk and behavior while creating and revising a concept map may reveal the active use, monitoring, and evaluation of knowledge that is not otherwise easily expressed by young children with developing language skills. The research reported in the present study investigates preschoolers' use of metacognitive control skills within the context of a small-group concept-mapping task.

1.1 Concept Mapping as a "Metacognitive Tool"

Concept mapping provides children opportunities to both monitor their own knowledge and control their thinking. In planning to build a map, the learner must reflect on prior knowledge, perhaps by asking "what do I know about…?" (McAleese, 1998). Children must make important planning decisions about which concept will be the focus of attention, where the concept will be placed on the map, and in what ways concepts may be linked to one another. By rearranging items on the concept map and hearing classmates' thoughts about conceptual relationships, children are able to consider multiple perspectives and multiple ways that the final goal may be reached. Finally, by "telling the story" of the map by following the path of the links, concept maps provide a powerful tool to check "sense-making," as well as a visual means to repair or make corrections if an error is detected (Gallenstein, 2005).

Although the ability to read and write is fundamental to understanding symbolic word meanings present in traditional concept maps, the task can be modified for children with developing literacy skills (Gallenstein, 2005). Rather than using words alone to represent concepts, concrete objects, pictures of objects, or picture word cards can be substituted in order to provide children the opportunity to participate at an appropriate developmental level. By

physically manipulating the concepts on a felt or magnetic board, and making connections using string, pipe cleaners, or arrows, children learn to organize their thoughts in a visual and kinesthetic way (Gallenstein, 2003).

1.2 Concept Mapping as Social Process

A great amount of adult guidance is necessary in order for very young children to effectively engage in a concept mapping activity. Limited verbal language and social skills sometimes make it difficult for young children to work cooperatively, share ideas with others, and take multiple perspectives (Fleer, 1992). In order to reduce task complexity to allow for children's full participation, individuals in a monitoring or overseeing role may structure the task by providing both external supports (limiting group size, reducing the number of concepts introduced) and regulatory supports (talking about each concept to elicit prior ideas, modeling metacognitive talk, reminding children of their ideas and questions, and teaching strategic behaviors).

In addition to structuring the activity and reducing complexity, the role of the teacher also involves helping the child understand the goals of the concept mapping activity and why certain actions are important in attaining those goals. For example, in selecting concepts to add to the map, the child must share in the intention to "make sense" of one or more concepts in order for the selection to be meaningful (McAleese, 1998). Likewise, the acts of placing concepts in relation to one another and specifying links between unconnected concepts require that the child thoughtfully consider the ways that new ideas relate to what is already known. The challenge for the teacher is to provide the kinds of support that are most conducive to children assuming metacognitive control, in which children both have opportunity and are motivated to direct their own mental activity.

2 Method

2.1 Participants

This study was conducted within the context of Science Start! - Early Reading First, a project funded by the Department of Education designed to enhance the development of language, cognition, and early reading skills of preschool children of low-income, minority, high-risk status using a language-rich science curriculum. The present study took place within a participating Head Start classroom located within a parochial school in an urban setting in the northeastern United States.

An experienced preschool teacher was invited to take part in the study due to her prior interest in concept mapping. The teacher, from this point forward referred to as "Mrs. S.," imparted the information regarding the classroom concept mapping activities to the two paraprofessionals in the room, "Mrs. C." and "Mrs. O." Mrs. S. conducted all large-group instruction in concept mapping, while all three adults participated in small-group mapping activities. A group of 17 4-year-old children assigned to the classroom of the participating teacher, consisting of 8 boys and 9 girls, were part of the targeted activity from which data was collected for the present analysis. The ethnicity of the sample consisted of 11 African-American students, 1 White/Caucasian student, and 2 students classified as "Other." At the time that the targeted concept mapping activity was observed, children ranged in age from 4 years 1 month to 4 years 10 months.

2.2 Procedure

Prior to beginning the study, the researcher met with Mrs. S. to gain access to the classroom and obtain consent. The researcher supplied Mrs. S. with reference literature and detailed information on how the units in the science curriculum could be adapted to incorporate concept mapping activities. Concept mapping was to be employed to teach key concepts already specified in the curriculum. The researcher then provided materials for Mrs. S. to use with her students, including a "mapping board" covered in felt, masking tape for the students to make links between concepts, and several sets of laminated picture word cards, backed with Velcro, consisting of photos of key concepts accompanied by their name.

The researcher visited the classroom and observed four separate "practice" units in which concept mapping took place, each unit consisting of 3-4 large group sessions in which the group built and revised a concept map over the course of one week. The first three units were employed to familiarize the children with materials, teach the children to understand maps as symbols, explain that placement of pictures on the board designated meaningful relationships,

and demonstrate that a set of concepts could be categorized several different ways. The fourth unit, "Pumpkins," served as the targeted unit in which discourse was to be analyzed for the facilitation and presence of metacognitive skills in adults and children. Specific topics in this unit included learning the parts of the pumpkin, learning how pumpkins grow, and learning how people can use pumpkins, for example, to carve a jack o'lantern or to bake pumpkin pie.

Concept mapping activities in the present study were modified in some important ways from activities typically used with older children and adults. Traditionally, concept maps have a hierarchical organization in which more general concepts appear at the top of the map, leading to more specific, less inclusive concepts at the bottom (Novak & Gowin, 1984). However, as the purpose of the activity was to teach new concepts to children whose language is still developing, it was more appropriate to reflect upon the multiple ways in which concepts may be related and understood, rather than focusing on a single relationship. Dynamic relationships can designate ways in which concepts cause, change, and influence each other (Safayeni, Derbentseva & Cañas, 2003), making the content more relevant and meaningful for children than solely statements referring to categorical membership.

Following the success of Figuerido et al. (2004), meaning was designated to different parts of the board; for instance, the right side of the board dealt with "how the pumpkin grows," while the left side of the board concerned "the parts of the pumpkin." Because many of the relationships between concepts were bi-directional (e.g., "the pumpkin has seeds," "seeds are inside the pumpkin"), and the focus was on learning dynamic relationships between concepts, arrows were not used. Instead, maps were typically "read" as text, from left to right and top to bottom. However, some cyclical relationships were also represented (see Figure 1). Cyclic maps capture how a system of concepts works together, providing contextual information indicating a larger process (Safayeni et al., 2003).

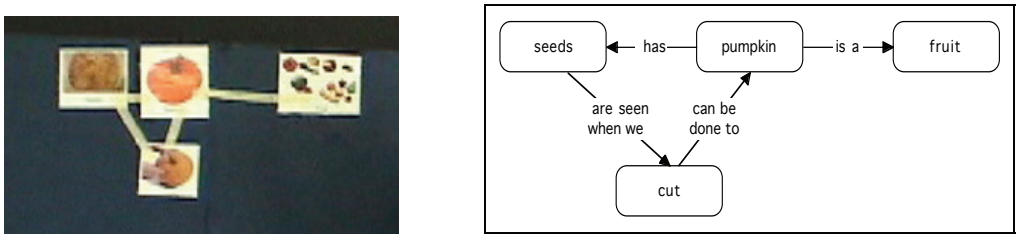


Figure 1. A cyclical relationship between pumpkin, cut, and seeds (constructed in large group).

A second issue concerns the representation of propositions, or the semantic units created by two or more concepts connected by a link that designates their relationship (Novak & Gowin, 1984). In traditional concept maps, propositions are represented by two concept labels connected by a linking word. However, because the children in the present study were pre-readers, the relationship between concepts was verbally stated rather than written. Figure 2 describes a section of a map and corresponding set of propositions that were verbalized in a small group.

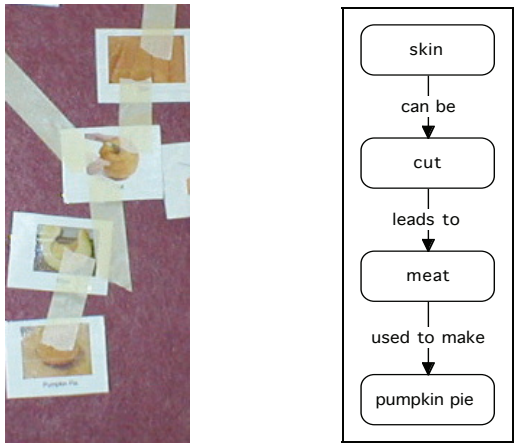


Figure 2. A hierarchical relationship between skin, cut, meat, and pie (constructed in small group).

2.3 Target Activity: Mapping the Pumpkin in Small Groups

On the last day of the "Pumpkins" unit, the class was asked to divide into three small groups, with one adult leading each group in constructing a concept map using the concepts the class had learned over the week. Prior to the target activity, Mrs. S. randomly assigned the children into groups. The target activity took place in small groups, rather than in the large group, in order to allow for a more detailed and thorough analysis of talk and nonverbal behavior in both adults and children. Evidence from prior research using concept mapping activities with young children suggests that small group metacognitive instruction tends to be most effective in promoting student engagement (Georghiades, 2000). Observations in each group were made concurrently using three separate video cameras. The videotapes, which ranged from 20 to 30 minutes in length, were transcribed verbatim. Nonverbal behaviors were also recorded alongside verbal utterances as they occurred in each interaction.

3 Results

The transcript from each group was coded and analyzed separately to explore adult-child talk during the concept mapping task, particularly in the ways that the discourse supported the children's use of metacognitive skills and strategies. Three types of adult supports were coded, including "Facilitates Planning," "Facilitates Monitoring of Progress," and "Creates Opportunities for Student Reflection." Table 1 provides examples from the transcripts illustrating each type of adult support and the activity during which each type of support took place (e.g., selection, placement, or connection of concepts). The excerpts show how teachers provided metacognitive supports prompting children to plan where to place a picture, examine the board for mistakes or missing information, and speculate about conceptual relationships.

	Concept Selection	**Concept Placement**	**Concept Connection**
Facilitates Planning	Which one you gonna do next? Which comes next?	Where do you think that water needs to be? Where we gonna put the skin?	Okay now what's another connector that we wanna do? What do you think it needs to join up with?
Facilitates Monitoring of Progress	Okay, what do we have left? We've got the skin of the pumpkin, the stem, the meat and cutting. Okay, now we're going to work on the inside of the pumpkin.	We didn't leave a spot for the seeds. Nothing's going on up here.	Are we happy with all of our connects? Or do we need to join something else together? We have a problem…the pumpkin patch isn't connected to anything.
Creates Opportunities for Student Reflection	Why should the vine be next? Put your thinking caps on, are we gonna see the meat before we cut it?	Does that make sense over there? Now does everybody agree with that? Why is the fruit next to the vine?	Why should we connect the jack o'lantern to the skin? Do you think you can make a story of why we connected it the way we did?

Table 1. Excerpts of Teacher Utterances Illustrating Metacognitive Skills Through Selection, Placement, and Connection Activities.

A second analysis addressed whether the three adults differed in the kinds of support they provided to the children. For each adult, the total number of utterances during the concept mapping interaction was recorded. The

total number of utterances indicating planning, monitoring, and reflection were also obtained for each adult, allowing a proportion to be calculated describing the frequency that each adult engaged in metacognitive support (Table 2). The proportions reflect that teachers differed in both the types of support provided and in the general tendency to emphasize metacognitive processes. Mrs. S. emphasized the monitoring of progress most frequently, as 20.19% of her utterances reflected monitoring activities. In contrast, Mrs. O. was most likely to emphasize planning, which was observed in 17.75% of her utterances. Mrs. C. demonstrated the lowest proportion of metacognitive supports, regardless of process, compared to the other two adults.

	Mrs. S. (N=431)		**Mrs. O. (N=445)**		**Mrs. C. (N=590)**	
Metacognitive Process	Raw Count	Percent of Total	Raw Count	Percent of Total	Raw Count	Percent of Total
Facilitates Planning	49	11.37	79	17.75	22	3.73
Facilitates Monitoring of Progress	87	20.19	48	10.79	33	5.59
Creates Opportunities for Student Reflection	29	6.73	51	11.46	6	1.02

Table 2. Number and Proportion of Teacher Utterances Facilitating Metacognitive Processes in Each Learning Group

Next, children's verbalizations and nonverbal behavior were analyzed to explore the extent that the participation in the concept mapping task was associated with metacognitive activity. Excerpts from the transcripts, shown in Table 3, reveal that children did engage in metacognitive control as they worked to build the concept map. Children were observed to exhibit planning statements in several ways: in selecting a concept ("how 'bout weighing?"); placement of a concept on the board ("meat right here"); and making a connection between two concepts ("soil to the digging"). Some children noticed problems or gaps in the map ("but they not connected to – this"). Children also made their preferences for choices in concept selection, placement, and connection known by pointing to the board and pictures.

	Concept Selection	**Concept Placement**	**Concept Connection**
Metacognitive Activity – Verbal	How 'bout weighing? We need this	Jack o'lantern here Cut it right here Put it down here Meat right here Cutting right here We need to go right here We can make it right here We need seed right here I would put the pumpkin pie – this	Connect it right there How 'bout this – to this? Seeds to the cutting I wanna connect it here This – to that We gotta get it connected Soil to the digging But they not connected to – this But we didn't get – not this

Table 3. Examples of Student Metacognitive Activity While Concept Mapping

Did children using "metacognitive talk" actually understand the goals of their participation, namely, in understanding their own knowledge and reflecting on ways that concepts are related to one another? According to the transcripts, the extent to which children came to understand the task goals appears to be directly related to the type of adult guidance provided. In many instances, after a child proposed a plan, suggested making a link, or chose to place a concept in a particular area on the board, the adults probed the child's decisions. Adult input often involved asking the children why they made a particular choice, prompting additional discussion about conceptual relationships. In the following example, a thoughtful discussion ensued as the group worked together to decide which concept was to be placed following "seeds" on the concept map:

Mrs. O: And where should the vine go? *(Holds picture of vine up briefly, then puts down.)*

Jason: Right here *(Jason points, then David points to same spot as Jason.)*
Mrs. O: Right where? (looks down at board) The vine should go right – right here? *(Places picture of vine where boys are pointing.)* Okay and why is that? *(Looks up at students.)*
Kelly: Because
Mrs. O: Why should the vine go here next? *(looks to the other end of the table.)* I'm talking to everybody at the table. Why should the vine be next? *(Looks up at students, pulling off a piece of tape.)*
Kelly: Because
Mrs. O: Okay because what Kelly – because what Kelly?
Kelly: Because
Mrs. O: *(raises eyebrows, leans in toward Kelly)*
Kelly: Because the seed is doin' that.

The questioning by Mrs. O. focused the children's attention on the goal that concepts were placed on the board for a reason, requiring children to not only make a decision but think about how it related to the larger goal of the concept map. Through conversation, Mrs. O. drew out Kelly's thoughts on the relationship between the seeds and the vine. In the next example, Mrs. S. clarified a relationship between two concepts that was prompted by a child's input:

Mrs. S: What's our first connect? Between the fruit and what? Between the fruit and…
Lexie: This *(Lexie connects two pictures with her hand)*
Mrs. S: Between the fruit and the seeds because fruit has seeds? *(looks at where Lexie is pointing.)* Good.

At times, if children's suggestions did not make sense, adults encouraged the children to reflect on concept relationships. In the next example, the children were deciding where to place the concept of water on the map. Mrs. S. encouraged the children to consider, before making a decision, about how water is something that is needed for plants to grow.

Mrs. S: Ok Tia, where do you think that water needs to be? *(Hands picture of water to Tia.)*
Daniel: Right here right here *(Daniel points to an empty spot on board in front of him.)*
Mrs. S: Well, we've got the planting stuff going on up here, so what do you think? *(Points to pictures on board.)*
Tia: *(Puts picture of water on board above picture of pumpkin patch.)*
Mrs. S: There, or do you think more up there? By the, where the, all the planting is? *(Points to spot near pictures of "planting stuff.")*
Tia: *(Picks up picture of water, moves picture to the location Mrs. S. suggested.)*
Mrs. S: There's the planting. Okay, what else do we need for the planting?

Students, when given the opportunity, were able to make meaningful decisions about where to place and connect concepts on the map, based on conceptual relationships. Were certain groups of children more or less likely to engage in metacognitive activity while building a concept map? In order to investigate group differences, the number of utterances indicating planning and evaluation were compared to the total number of utterances for each group. Findings suggest that children in Mrs. C's group demonstrated a lower proportion of metacognitive utterances compared to children in the other two groups (Table 5). This finding is consistent with the observation that Mrs. C. provided little metacognitive support to her group of students during the activity.

	Mrs. S.'s group (N=109)		**Mrs. O.'s group (N=151)**		**Mrs. C's group (N=202)**	
Metacognitive Process	Raw Count	Percent of Total	Raw Count	Percent of Total	Raw Count	Percent of Total
Demonstrates Planning	8	7.3	12	7.9	6	3.0
Demonstrates Evaluation	7	6.4	12	7.9	3	1.2

Table 5. Number and Proportion of Student Utterances Indicating Metacognitive Processes in Each Learning Group

Mrs. C. not only provided little metacognitive scaffolding, but also used statements tending to discourage self-directed thinking on the part of the students. Mrs. C. emphasized that children participate by placing and taping

concepts on the map according to her direction, rather than taking responsibility for thinking and decision-making. For example, she used many imperatives, such as "get the pumpkin patch picture" during concept selection, "put it down next to the fruit" during concept placement, and "put that between the soil and the sun" during concept connection. Mrs. C. framed the entire task by stating, "remember, you don't answer, you don't get to put the stuff on the board." When a student's comment did not make sense, Mrs. C. commented, "you're not, you're not giving me any answers" rather than working to attain a shared meaning. These phrases, focused on outcome rather than process, likely undermined the potential for the concept map to promote children's reflection and monitoring.

4 Discussion

This investigation has shown that with appropriate adult supports, concept maps are beneficial in facilitating preschoolers' metacognitive control, including planning, evaluation, and correction. This present study is one of the few studies to examine the benefit of using concept mapping tasks with children of preschool age, and the first to document the ways that preschoolers are able to learn, practice and develop important self-regulatory skills through building a concept map.

This study broadens the ways in which processes involved in construction and monitoring of a concept map are understood. Specifically, examining the extent to which engagement in a concept mapping activity facilitates metacognitive control highlights the ways that socially shared activities are transferred into internal processes within the student (John-Steiner & Mahn, 1996). Concept mapping has sometimes been described in the literature as a "student-directed strategy that does not rely on teacher involvement" (Chularut & DeBacker, p. 260). However, the findings of the present study tend to refute this view, suggesting instead that, in certain circumstances, it is the initial social interaction, through "wrapping language around" the activity, that help learners understand goals and purposes that give the concept mapping task its meaning.

The present findings have important implications for any teacher with a goal of enhancing students' regulatory thinking skills with the use of concept maps, regardless of the age of the learner. Although concept maps are by their nature tools that promote mindful reflection, students may or may not take full advantage of the benefits of concept mapping, depending on the instructional procedures implemented. The degree that the concept mapping task facilitates self-regulated learning within the student will ultimately depend on the educational climate in which the task is introduced. Ideally, the learner and teacher together will build a shared meaning regarding the value of the concept mapping task in emphasizing thought, reflection, and mastery.

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References

August-Brady, M. (2005). The effect of a metacognitive intervention on approach to and self-regulation of learning in baccalaureate nursing students. *Journal of Nursing Education, 44*(7), 297-304.

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F.E. Weinert & R.H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 65-116). Hillsdale, NJ: Erlbaum.

Chularut, P. & DeBacker, T.K. (2004). The influence of concept mapping on achievement, self-regulation, and self-efficacy in students of English as a second language. *Contemporary Educational Psychology, 29*, 248-263.

Cox, B.E. (1994). Young children's regulatory talk: Evidence of emerging metacognitive control over literary products and processes. In R.B. Ruddell & H. Singer (Eds.), *Theoretical models and processes of reading* (4th ed., pp. 733-756). Newark, DE: International Reading Association.

Figueiredo, M., Lopez, A.S., Firmino, R. & de Sousa, S. (2004) "Things we know about the cow:" Concept mapping in a preschool setting. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Fleer, M. (1992). The suitability of an interactive approach to teaching science in early childhood. *Australian Journal of Early Childhood, 17*(4), 12-23.

Gallenstein, N.L. (2003). Creative construction of mathematics and science concepts in early childhood. ED473843.

Gallenstein, N.L. (2005). Never too young for a concept map. *Science and Children, 43*(1), 44-47.

Georghiades, P. (2000). Beyond conceptual change learning in science education: focusing on transfer, durability and metacognition. *Educational Research, 42*(2), 119-139.

John-Steiner, V. & Mahn, H. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist, 31*(3&4), 191-206.

McAleese, R. (1998) Coming to know: The role of the concept map – Mirror, assistant, master? ED429968.

Mintzes, J.J., Wandersee, JH. & Novak, J.D. (1997). Meaningful learning in science: The human constructivist perspective. In G.D. Phye (Ed.), *Handbook of academic learning: Construction of Knowledge* (pp. 405-447). San Diego: Academic Press.

Novak, J.D. & Gowin, D.B. (1984). *Learning how to learn*. Cambridge: Cambridge University Press.

Safayeni, F., Derbentseva, N., & Cañas, A. J. (2005). A Theoretical Note on Concept Maps and the Need for Cyclic Concept Maps. *Journal of Research in Science Teaching, 42*(7), 741-766.

Salomon, G. & Globerson, T. (1987). Skill may not be enough: The role of mindfulness in learning and transfer. *International Journal of Educational Research, 11*, 623-638.

Stow, W. (1997). Concept mapping: A tool for self-assessment? *Primary Science Review, 49*, 12-15.

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USING CONCEPT MAPS TO ASSESS THE SCIENCE UNDERSTANDING AND LANGUAGE PRODUCTION OF ENGLISH LANGUAGE LEARNERS

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Abstract: This paper describes the use of concept maps to assess the understanding of science concepts and science language production of elementary students who are English languages learners (ELL). The assessment of science content understanding in ELL students is particularly challenging because it is difficult to determine whether students' performance reflects their understanding of the concepts or their language proficiency. Concept maps allow students to demonstrate what they have learned in their primary or second language or both, in a task where the linguistic demands are minimized. A method is described which evaluates 400, grades 2-5 ELL student's performance in four categories: (1) number of propositions, (2) scientific accuracy, (3) depth of explanation and (4) science vocabulary. The results show that concept maps can be used to assess growth in ELL understanding of science concepts.

1 Introduction

The availability of appropriate science assessments is an issue facing many educators as they make steps toward implementing inquiry-based instructional approaches in the elementary classroom. It is difficult to measure student learning in open-ended inquiry learning environments. Traditional closed-ended methods of assessment, such as multiple choice tests, do not capture students' ability to develop and carry out independent investigations nor do they measure the development of student conceptual understanding (Escalada & Zollman 1997, Ruiz-Primo & Shavelson , 1996b). Ruiz-Primo & Shavelson proposed the use of concept maps as alternatives to the use of closed-end assessments. Concept maps are grounded in a psychological theory which focuses on individuals and how they integrate new learning into existing conceptual frameworks by making explicit, conscious connections between concepts as a way to integrate information into memory (Ausubel 1968; Ausubel, Novak, & Hanesian 1978; Novak & Gowin 1984; In science instruction, the concept map activity (CM) focuses on students' ability to use science language to represent their understanding of science concepts. The basic form of a concept map consists of words or phrases that are connected together with linking words or phrases to form complete thoughts called 'propositions' (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996a; Stoddart, Abrams, Gasper, & Canaday, 2000). The validity of the CM activity as a science assessment has been established through correlation with other science content measures and external science standards such as text books, science web-sites, and research scientists (Stoddart et al, 2000). Student scores on concept maps have been shown to be correlated with scores on conventional assessments, including teacher developed tests and national standardized tests (Farrokh & Krause 1996; Liu & Hinchey 1993; 1996; Rice, Ryan & Samson, 1998; Wilson 1993).

The assessment of science content learning is made even more completed by the increasing number of U.S. students who do not speak English as a first language. The assessment of content understanding in English Language Learners (ELL) is particularly challenging because it is difficult to determine whether students fail to perform because they have not mastered the concepts, or because they simply lack the linguistic resources to demonstrate what they have learned (Met 1994). An appropriate assessment allows students to demonstrate what they have learned; what they do know and can do, not what they do not know and cannot do. Concept maps allow students to demonstrate what they have learned in their primary language in a task where the linguistic demands are minimized.

This paper proposes that concept mapping is a particularly useful assessment in measuring ELL students' science and language learning in an inquiry science learning environment. The linguistic task demands can be tailored to students' level of language proficiency. The content demands can be tailored to the specific content that an individual student or class pursues. In addition, concept maps can be used to measure both science understanding and the development of academic science vocabulary. Science vocabulary plays an important role in learning science because it involves a process of developing relationships among ideas, terms and meanings (Fradd and Larrinaga McGee 1994, Lemke 1990). Concept maps focus on these relationships. This paper presents a method to use concept maps as assessment of science and language learning for ELL students.

2 Concept Map Activity

The CM activity in this study is incorporated into classroom instruction and designed to assess the content students are currently learning. The classroom teacher and/or researcher identify the key concepts within a unit of science that will be taught. Using this overall list of concepts, they chose three 'superordinate' concepts—those which would elicit from students the broadest possible range of related concepts. For example, for a unit on 'Habitats' a teacher might choose; habitat, living, nonliving rather than soil, grass, mouse. These three superordinate concepts are used as prompt words for students when they began the concept map activity. Things to keep in mind for choosing the three overarching concepts include: (1) they should be central concepts to the unit topic; (2) they should be broad enough to help initiate students' brainstorming about other concept words; (3) if the concept map activity is being used as pre and post assessment, the overarching concepts should be words that are meaningful to students even before instruction. Students are given a list of the three overarching concepts, and four to seven additional spaces (depending on their grade leveli) to generate their own concept words that relate to the topic. Once students complete their list of concepts, they are instructed to use these words to build a concept map (see Table 1 below).

Nombre/Name:_____ Fecha/Date_____

Maestra/Teacher:_____

Este trabajo tiene dos partes.

1) Escoja 4 palabras sobre **los cambios que las plantas pasan durante su desarrollo** que usted crea son conceptos importantes. Pongalas en la lista abajo. Tendra un total de 7 conceptos.

2) Use estos 7 conceptos para hacer un mapa de conceptos que muestre lo que sabe de **los cambios que las plantas pasan durante su desarrollo**.

This job has two parts.

1) Choose 4 words about **the changes that plants go through** that you think are important concepts. Add them to the list below. You will have a total of 7 concepts.

2) Use these 7 concepts to make a concept map to show what you know about **the changes that plants go through**.

1) Plantas
Plants

2) Cambios
Changes

3) Ciclos
Cycles

4) _____

5) _____

5)_____

7)_____

Table 1: Concept Map Protocol

The concept map administration protocol consists of three parts. In the first step, introduction to concept mapping, a trained administrator provides direct instruction and modeling on how to make a concept map, with

students participating verbally and constructing a group concept map. In the second step, students are provided with the three overarching concepts, and asked to generate a word list of additional concept words that are related to the main topic. In the third step, students produce their own concept maps using the word bank they had just generated. Introduction of the activity is designed to take less than 25 minutes. Instruction is conducted in students' primary language. Students are not expected to construct a map on their own.

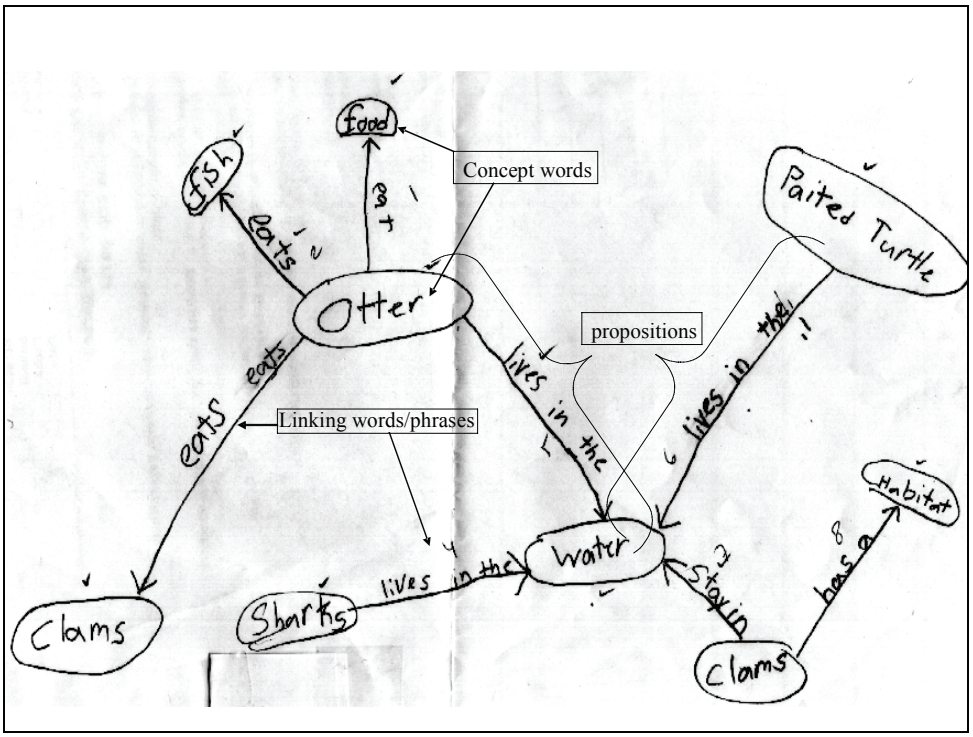


Figure 1: Concept map produced by a third grade ELL student

3 Scoring and Results

Criteria were developed to assess ELL student on science content understanding and the use of science language. The concept map protocol was administered to 200 2nd through 5th grade ELL students attending a four week science summer school program for children of migrant agricultural workers from Mexico. The students had a range of language proficiency but most were beginning and intermediate English language speakers. The concept map activity was presented by the classroom teacher and researcher using the standard protocol. Concept maps were produced at the beginning and end of a four week science instructional unit which taught earth science through a garden curriculum. The concept maps were scored by two trained researchers. Inter-rater reliability was .80.

3.1 *Science Content Understanding*

The concept maps are scored on three science content criteria: (1) overall number of propositions, (2) scientific accuracy and (3) depth of explanation.

3.1.1 Number of Propositions

The open-ended nature of the concept mapping task allows students to produce as many or as few propositions as they see fit to express their understanding. Looking at the overall number of propositions on the pre- and post-assessments provides a broad overview of student performance. As Figure 2 shows,, the participating students significantly increased in the number of propositions per map, from an average of 5.98 to 7.77 [$F=3.214$, df (2,99), $p<.05$]. This result indicates that students were able to write more propositions on the main topic at the end of the

unit as compared to the beginning. It is a broad overview; it does not take into account familiarity with the task or scientific accuracy of the propositions.

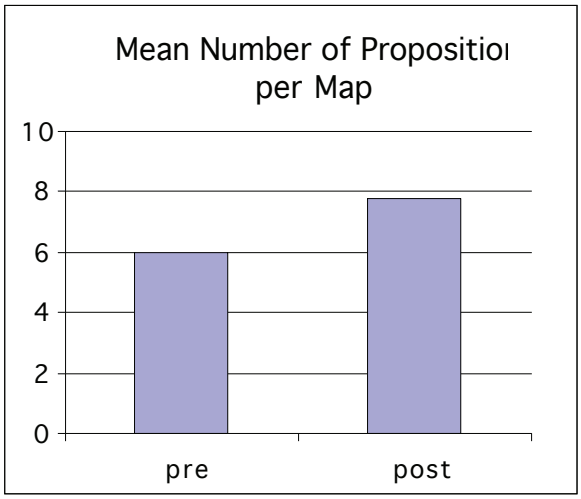


Figure 2: Mean Number of Propositions in pre- and post-assessments

3.1.2 Accuracy

Student concept maps were scored on four levels of Accuracy: 1. scientific accuracy, 2. common knowledge, 3.) inaccurate statements, and affective statements. See Table 2.

1. Scientific accuracy is defined as correct statements about scientific content, with 'scientific' meaning content which is typically learned in grade school science curricula, content of a particular field of science, and content learned from the scientific process. The latter includes specific observations such as exact measurements.

2. Common knowledge is defined as non-scientific, everyday knowledge. This includes topics such as playing, and material needs of people.

3. Inaccurate statements are those that are commonly accepted by scientists to be incorrect, at the level of complexity appropriate to grade school science curricula. Inaccurate statements comprise less than 10% of the overall group of maps. This is most likely due to the open-ended nature of concept mapping, where students are asked to report what they do know, rather than address specific content areas that may be beyond their expertise.

4. Affective statements are defined as those that express emotions, feelings or personal thoughts.

Category	Score	Example
Accuracy	Scientifically Accurate	Roots need water
	Common Knowledge	Kids play with dogs
	Inaccurate	Dinosaurs eat gorillas
	Affective	I love flowers

Table 2: Categories of scientific accuracy

To take into account the change in overall number of propositions, scientific accuracy is analyzed as the ratio of these propositions to the overall number of propositions. Pre- and post-assessment showed that school students significantly increased the proportion of scientifically accurate propositions in their maps from 13.9% to 52.5% [$F=6.16$, $df(1,100)$, $p<.05$]. See Figure 3.

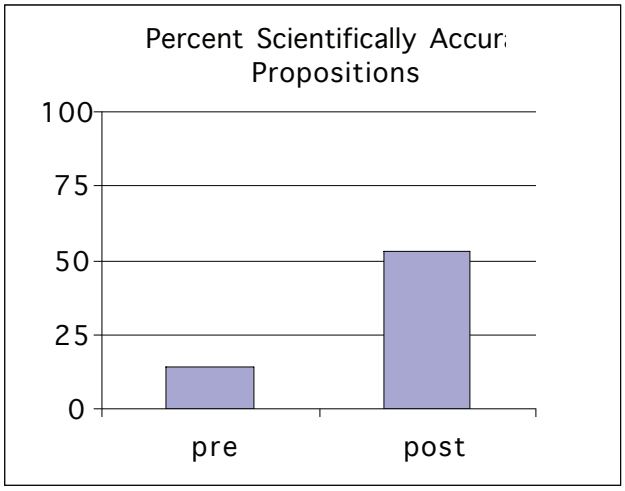


Figure 3: Percent of scientifically accuracy propositions in pre- and post-assessments

3.1.3 Depth of Explanation

The Depth of Explanation criterion differentiates between: 1. factual statements; 2. extended factual statements; 3. higher order explanations. See Table 3.

1. Factual statements are defined as subject-verb-object propositions that provide basic descriptions or informational statements, and do not attempt to provide explanations concerning function or purpose. They often answer 'what' questions.

2. Extended factual statements contain additional elaboration beyond subject-verb-object, such as additional clauses. They provide basic descriptions or informational statements, and do not attempt to provide explanations concerning function or purpose. They often answer 'what' questions.

3. Higher-order explanations are defined as propositions that describe function or purpose. They often address 'how' or 'why' questions. The researchers have empirically found in other studies that higher-order explanations comprise more elaborate grammatical structures than subject-verb-object, and are therefore not divided into two groups as the basic descriptions.

Depth of Explanation	Factual	Plants need sunlight
	Extended factual	Plants need sunlight in order to grow
	Higher-order explanation (answers 'how' or 'why')	Plants use sunlight and carbon dioxide to produce their own food

Table 3: Depth of explanation categories

To take into account the change in overall number of propositions, depth of explanation are analyzed as the ratio of both extended factual and higher order explanation to the overall number of propositions. There was no significant change in the 'depth of explanation' score over the course of summer school. These results are not surprising, given the short period of instruction being assessed and the age of the students participating in the study. More complex levels of understanding develop over an extended period of time. In addition, younger students offer less elaborated explanations than older students. The students, however, did make significant gains in scientific accuracy, which is a precursor to developing higher order understandings.

3.2 Science Language

The vocabulary component is used to evaluate students' use of language in the concept maps. The focus is primarily on students' ability to incorporate science vocabulary in their explanations of science concepts. Science language is classified as: 1. common or 2. specialized. See Table 4.

1. Common refers to science words that are developmentally appropriate for both social and academic discourse by students, for example, 'tree,' 'sun,' 'plants,' and 'dirt'.

2. Specialized refers to science terms that are specific to an academic science discipline. This category of science terms contains: (1) terminology specific to a cognitive, academic setting, that are not common in social discourse, such as 'thermal energy,' 'cytoplasm,' and 'mitochondria,' and (2) science words internalized from an academic setting, such as 'Fahrenheit,' 'cells,' and 'atoms.'

Category	**Examples**			
	Common		**Specialized**	
Chemistry	Hot salt water	Caliente sal agua	oxygen convection atoms	oxígeno convección átomos
Physics	Light color sound	Luz color sonido	gravity thermal energy force	gravedad energía termica fuerza
Physical Geography	Rain moon mountain	Lluvia luna montaña	solar tide fossil	solar marea fósil

Table 4: Earth Science Vocabulary Examples in English and Spanish

As Figure 4 shows, students' use of both common and specialized Earth Science vocabulary significantly increased over the course of summer school [common: $F=5.28$, $df(1,104)$, $p<.05$; specialized: $F=8.83$, $df(1,104)$, $p<.005$].

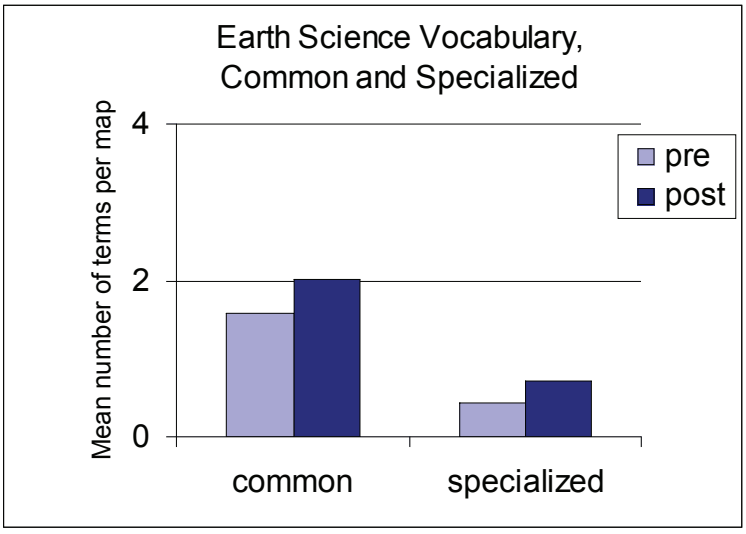


Figure 4: Science Language

4 Summary

This paper described and tested a concept map methodology to measure the development of ELL students' science understanding over the course of a four-week science inquiry summer school. The concept mapping technique was selected because: it is curriculum-sensitive; it focuses on what the students know, rather than what they don't know;

it does not require students decode or to produce extensive text; it can be completed in either English or Spanish or a combination of both languages. In addition, concept maps can be used to measure both science content and the use of science language. The results show that student learning can be reliably assessed using this method. The data from the concept maps demonstrate that there was a significant increase in students' science understanding over summer school. The proportion of scientifically accurate concepts that the students produced increased from 14% to 53% in the pre and post assessments. Students also showed significant growth in their scientific vocabulary. They increased in their ability to use both common scientific terms and specialized scientific terms in life and earth sciences. The increase in both accuracy of content understanding and the use of scientific vocabulary suggests that students were able to learn both science content and the academic language of science.

5 References

Ausubel, D. (1968). *Educational Psychology: A Cognitive View*. New York: Werbel and Peck.

Ausubel, D., Novak, Joseph D. & Hanesian, H. (1978). *Educational Psychology: A Cognitive View*. NewYork: Holt, Rinehart and Winston.

Escalada, L.T. & Zollman, D.A. (1997). An investigation of the effects of using interactive digital video in a physics classroom on student learning and attitudes. *Journal of Research in Science Teaching*, 34,467-489.

Farrokh, K. & Krause, G. (1996). The Relationship of Concept-Mapping and Course Grade in Cell Biology. *Meaningful Learning Forum* 1.

Fradd, S.H. & Larrinaga McGee, P. (1994) *Instructional assessment: An integrative approach to evaluating student performance*. Redding, MA: Addison-Wesley.

Lemke, J. (1990). *Talking science: Language, learning and values*. New York: Ablex.

Liu, Xiufeng & Hinchey, Michael (1993). *The Validity and Reliability of Concept Mapping as an Alternative Science Assessment*. Paper presented at the Third International Seminar of Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, NY.

Liu, X. & Hinchey, M. (1996). The internal consistency of a concept mapping scoring scheme and its effect on prediction validity. *International Journal of Science Education*, 18.

Met. M. (1994). Teaching content through a second language. In F. Genessee (ed.) *Educating second language children: The whole child, the whole curriculum, the whole community*. (pp. 159-182), New York: Cambridge University Press.

Novak, J.D. & Gowin, D. B. (1984). *Learning how to Learn*. Cambridge, England: Cambridge University Press.

Rice, D.C.; Ryan, J.M. & Samson, S.M. (1998). Using Concept Maps to Assess Student Learning in the Science Classroom: Must different methods compete? *Journal of Research in Science Teaching*, 35(10):1103-1127.

Ruiz-Primo, M.A. & Shavelson, R.J. (1996a). Problems and Issues in the Use of Concept Maps in Science Assessment. *Journal of Research in Science Teaching*, 33(6): 569-600.

Ruiz-Primo, M.A. & Shavelson, R.J. (1996b) Rhetoric and Reality in Science Performance Assessments: An Update. *Journal of Research in Science Teaching*, 33(10): 1045-1063.

Stoddart, T, Abrams, R., Gasper, E., & Canaday, D. (2000) Concept maps as assessment in science inquiry learning – a report of methodology. *International Journal of Science Education*, 22(12), 1221-1246.

Wilson, J.M. (1994). Network representations of knowledge about chemical equilibrium: Variations with Achievement. *Journal of Research in Science Teaching*, 31, 1133-1147.

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USING CONCEPT MAPS TO INTEGRATE RESULTS FROM A COGNITIVE TASK ANALYSIS OF SYSTEM DEVELOPMENT

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Abstract A case can be made that the current US system for procuring large-scale information technologies is partly responsible for resulting in systems that are user-hostile, when they should be human-centered (Hoffman & Elm, 2006). Systems for both training and decision aiding cause automation surprises and create a need for kluges and work-arounds. A cognitive task analysis of systems development was conducted in which a number of highly experienced program developers and managers were interviewed, to identify factors contributing to current high rates of systems development failure and to determine ways in which the principles and methods of cognitive systems engineering might be integrated into systems development. Results of the analysis were depicted in Concept Maps that provide a broad overview of procurement. Concept Maps are used to identify and characterize system development activities, challenges, and strategies. The results affirm the claim that current systems development frameworks and methods are incompatible with known principles of human-centered computing and cognitive systems engineering. Looking ahead, the Concept Maps will be used as a springboard for creating new approaches to procurement, including the representation of system requirements, and the development of new systems to support development teams in achieving and maintaining common ground and addressing challenges of creating human-centered systems for complex cognitive domains.

1 Introduction

The failure rate among software development projects is notoriously high. The Wall Street Journal has reported that 50% of software projects fail to meet expectations and 42% of corporate information technology projects are discontinued before completion (cited by Coyle, 1999). A 1995 US Department of Defense study estimated that 46% of the system development efforts it funds result in products that are not successfully used and 29% never even produce a product (cited by Leishman & Cook, 2002). These statistics translate into practitioners who lose out because they don't have the systems they need to perform their work effectively, not to mention billions of dollars squandered. For example, the US Internal Revenue Service spent $4 billion dollars on computer systems that, in the words of an IRS official, "do not work in the real world" (Marketplace, January 31, 1997). The U.S. Federal Bureau of Investigation spent $170 million dollars on a problem-riddled software development effort before abandoning it (Eggen, June 6, 2005). In general, large-scale information processing (or "intelligent") systems, for both training and decision aiding, cause automation surprises and create a need for kluges and work-arounds (Koopman & Hoffman, 2003). This means that even those system development efforts that are successfully implemented tend not to support their users. Research suggests a myriad of complicated methodological, cultural, organizational, managerial, and technological factors are to blame (e.g., Davenport, 1998; Freeman, 2001; Nah, Lau, & Kuang, 2001; Whittaker, 1999).

Our preliminary discussions with systems developers suggested that Spiral and Waterfall modeling (and their variants) are often used to frame system development efforts, but subsequently end up as mere cover stories to describe the system development process. What people say they do often is not what they actually do. In addition, we came to suspect that "user involvement" in the design process is usually too little and too late. Worse still, the kinds of evaluations and verifications that are typically involved are based on a "satisficing" criterion—that is, users work with the new system for a while and then are queried concerning their opinions (completing what some system developers call "smile sheets"), resulting in evidence that some people like it, more or less, at least some of the time. Thus, we perceived an opportunity to pursue the implications of Human-Centered Computing for the procurement process, in particular the fact that requirements specification is not regarded as a process. "Requirements creep" is seen as a negative thing, a thing to be avoided, when an empirical looks suggests that it is an inevitability (Hoffman & Elm, 2006). An example of the sometimes stark disconnect between the procurement process and human-centering shows clearly in one statement in a US Department of Defense procedural guide (DoD, 1996): "Design efforts shall minimize or eliminate system characteristics that require excessive cognitive, physical, or sensory skills (Para. C5.2.3.5.9.1)." In effect, this translates to a built-in push to create systems that can actually prevent the achievement and exercise of expertise.

To follow-up on the disparity, we found an opportunity to take an empirical approach and have a detailed look at what really happens in the procurement of large-scale information processing and decision-aiding systems. We pursued our initial findings by conducting a cognitive task analysis to seek a more detailed insight into the reasons for the high rate of systems development failure. In particular, the analysis was conducted to identify factors contributing to the failure rate and ways in which cognitive systems engineering principles, methods, and tools might contribute to reducing the rate. The cognitive task analysis involved an assessment of the systems development literature and the elicitation and assessment of the knowledge and beliefs of systems engineers. The results were used to create a number of Concept Maps using CmapTools (Cañas et al., 2004) that will be used to guide an effort at creating new approaches and methods for procurement.

2 Cognitive Task Analysis

We conducted a documentation analysis, of about 50 sources. The sources included widely cited books such as *The Mythical Man-Month* (Brooks, 1995) and *Rapid Development* (McConnell, 1996), government acquisition and systems engineering publications such as the *DoD Architecture Framework* (DoD, 2003), website content describing systems engineering frameworks and methods (e.g., the Systems Modeling Language [SySML] and the Capability Maturity Model® Integration [CMMI®]) process, and journal articles and technical reports addressing systems development and acquisition methods and tools, challenges, principles, and practices. Examples are titles such as *Common Errors in Large Software Development Projects* (Gaitros, 2004) and *Weaving Together Requirements and Architecture* (Nuseibah, 2001). Our documentation analysis highlighted some limitations in systems development, that is, key contributors to the failure rates described above. Each category of limitation can be expressed as a major systems development challenge that currently is not being adequately addressed:

- Identifying and meeting user work support needs,
- Accommodating new information and requirements across the system development effort and system lifespan,
- Maintaining team coordination, and
- Coping with the complexity involved in large-scale procurements.

We conducted in-depth interviews with six individuals having at least 20 years of experience in software engineering, including experience either as managers of large-scale procurement projects, leaders of teams of software engineers, or systems engineers in large-scale procurement projects.

Five participants were interviewed (taking about 2-hr per session). The sixth participant participated in two 2-hr sessions. The interview protocol was based on the Critical Decision Method (CDM; e.g., Hoffman, Crandall, & Shadbolt, 1998) and the Standard Operating Procedure knowledge elicitation method (Hoffman, Ford, & Coffey, 2000). Both procedures support the participant in the recall of a past challenging or difficult systems development project, and included probe questions for eliciting more detail about specific systems development practices—for example, the conditions under which a practice occurs, the expertise required, and the value and true purpose. The cases that were discussed included, for example, the procurement of a decision support system for aircrews, the upgrade of a legacy training system, and the development of interfaces for an electronic library.

Each interview transcript was broken down into a series of 'transcript chunks,' where each chunk explained a single concept or made a particular argument. Each transcript chunk was assessed to determine the system development activities to which it related, and was coded in terms of types of system development activity (e.g., "risk management," "coordinate with customer"), and challenges to system development (e.g., "shifting requirements," "team coordination and conflict management"). These data were represented in two ways. One was in the form of timelines having the purpose of showing when in the procurement and system development process activities are performed and when some new form of support tool might be useful to program stakeholders. For example, interview data suggested that significant effort was required to foster interactions among development sub-teams, among different contractors working on the same system, and between the team and the sponsor. However, these types of coordination activities are largely neglected by current frameworks and by the support tools that are used in systems development.

We also represented the results in the form of Concept Maps. The purposes of these were to paint a broad picture of the procurement/system development process, to capture some of the strategies that effective managers

used to cope with the challenges, and to lay out the relations of all of the various stakeholders who need to maintain common ground during system development activity. In addition to the challenges, the themes identified across interviews included strategies for coping with the challenges of evolving requirements and the challenges of team coordination. With few exceptions (the use of whiteboard meetings and conversation), strategies were applied relatively inconsistently across development efforts, and seem to have varied considerably with respect to their effectiveness.

3 Example Concept Maps

Concept Maps we have developed capture findings of the cognitive task analysis and our ideas about how to use human-centering principles to address systems development and procurement deficiencies identified in that analysis. The first example Concept Map (Figure 1) presents a broad view of the shortfalls in current system development processes. This Concept Map integrates information from the literature review and the interviews. Figure 2 exemplifies a set of Cmaps that describe solutions to current systems development challenges. We are using this set of Concept Maps to shape new approaches and methods to systems development. This particular Concept Map describes the challenge of attaining *common ground* within the system development team and the means by which common ground may be achieved to help minimize problems associated with team coordination. Figure 3 shows one of a number of specific topics that were brainstormed as we reviewed and analyzed the interview data. Concept Maps such as this might be used by development teams to provide a rationale for requirements, in this case testable hypotheses about a new technology (haptic interfaces) to be integrated into a training system. Note that this Concept Map utilizes the "nested node" capability, in this case to highlight hypotheses concerning the use of haptic interfaces on training. Nested nodes are nodes that group a number of nodes (and their links) together within a single node. A nested node can be expanded (or collapsed) by clicking on the arrow box at the right-hand side of the nested node. Expanded nested nodes appear as large grey boxes in Figure 3.

4 Discussion

The cognitive task analysis results captured in the Concept Maps show that existing systems engineering and acquisition methods are inadequate in critical ways. They fail to support domain assessment. They fail completely to cope with the problem of emerging and changing requirements. They do not address team coordination sufficiently. These challenges are associated with: (1). An inadequacy of current artifacts (i.e., information and documentation management tools and documentation formats and categories), (2). Conflicts among engineers who use different approaches, and (3). Politics and agendas among individuals and organizations with different priorities that are often at odds with the goal of making systems that are usable, useful and understandable to the people who will be the eventual users of the systems.

The findings suggest that all stepwise descriptions of system development (i.e., spiral and waterfall modeling) are misleading. The empirical reality of systems development is that it is a macrocognitive activity in which key functions are parallel, simultaneous and highly interdependent (Klein, et al., 2003). The macrocognitive nature of systems development can be predicted on the basis of the laws of cognitive work and notions of Human-Centered Computing (Hoffman, et al., 2004; Hoffman & Elm, 2006). These laws and notions should be used to develop frameworks and methods that facilitate the true work of systems development. Accordingly, our goal is to use the results of the work reported here, especially the Concept Maps, to guide the development of a new systems engineering and acquisition framework. The framework, called the *Joint Systems Engineering Method* (JSEM), will hopefully address systems development challenges, support systems development in an empirically honest manner, and draw principles and methods of cognitive systems engineering and human-centered computing into systems development.

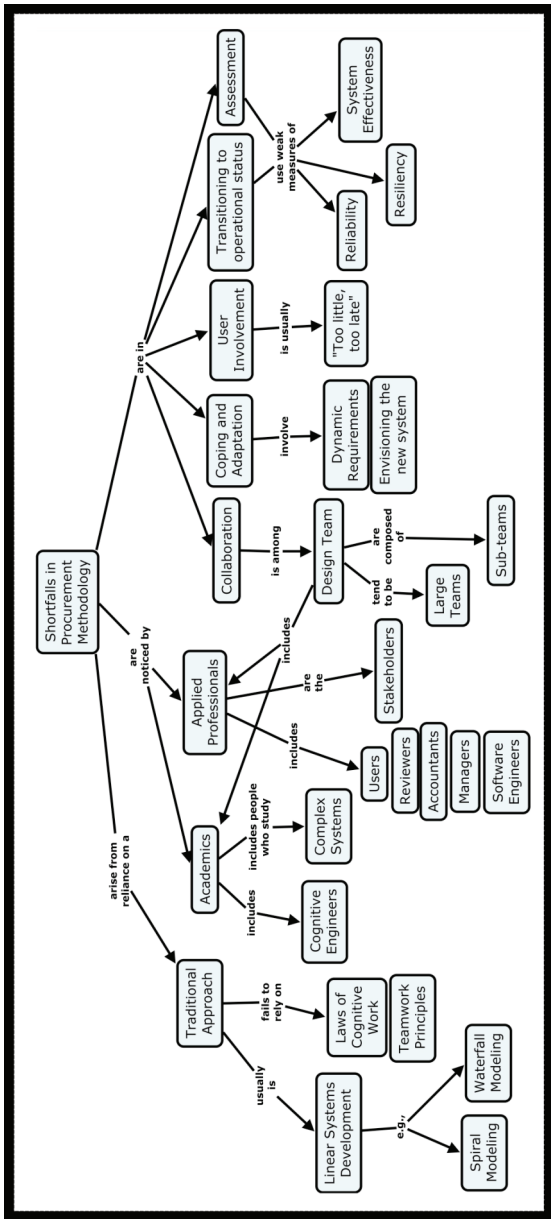


Figure 1. A Concept Map about shortfalls in the system development/procurement process.

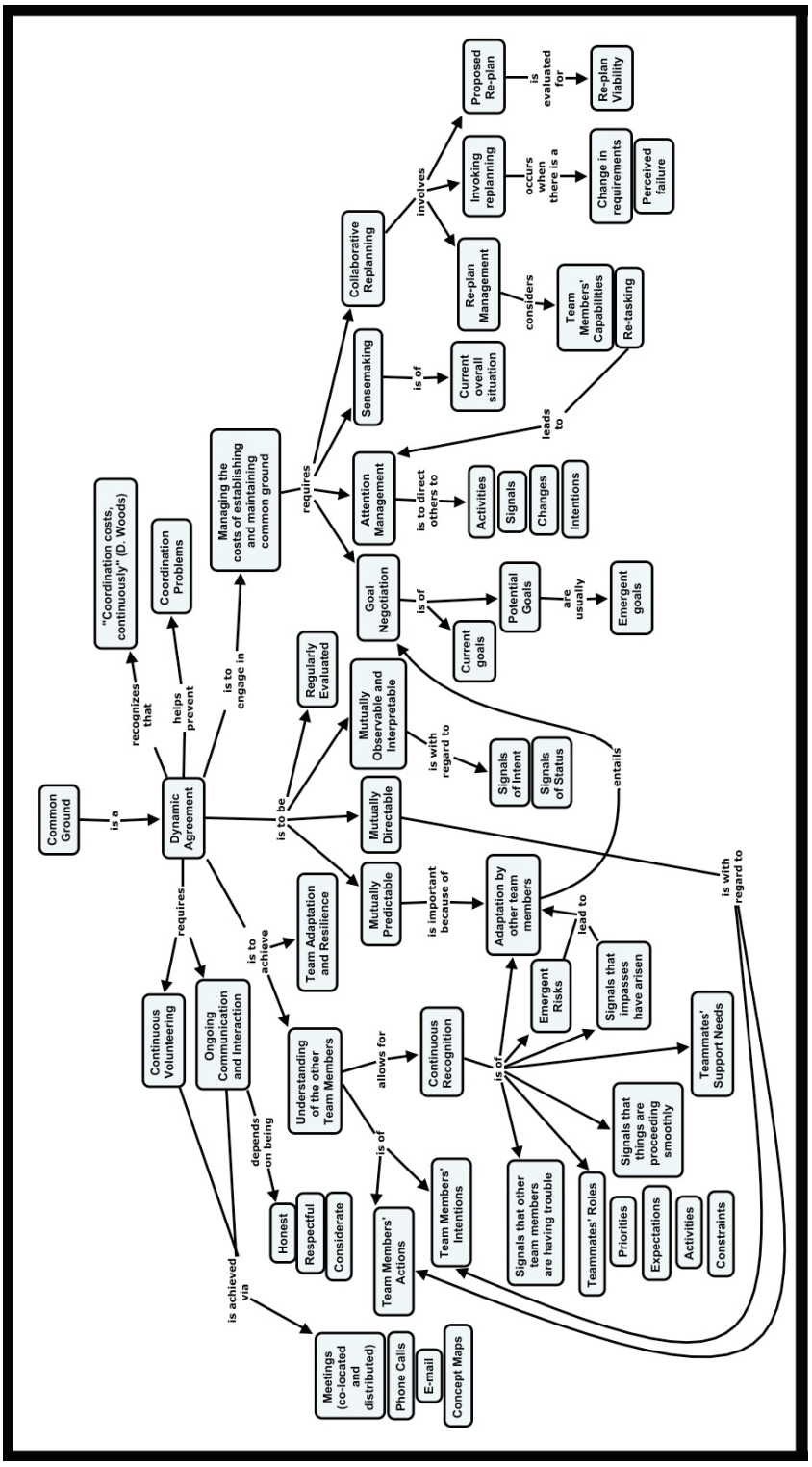


Figure 2. A Concept Map about the challenge of maintaining common ground.

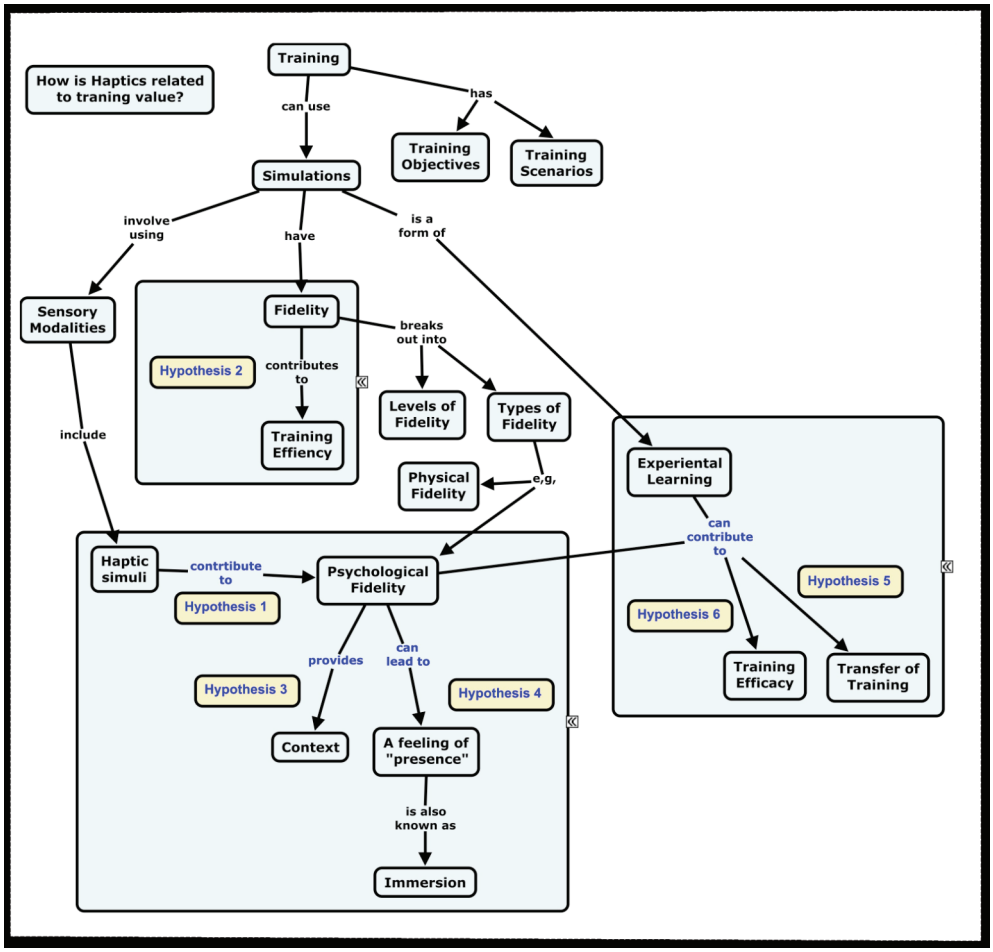


Figure 3. A Concept Map about hypotheses concerning training design.

Concept Maps additionally may contribute to the development of methods and tools that improve the roles of principles and methods of cognitive systems engineering and human-centered computing in systems development. Figure 3 demonstrates to us how a Concept Map can help a team capture the rationale for requirements and thereby contribute to informed risk management and decision making about requirements with respect to human-centered as well as more common technology-centered requirements. Concept Maps also have potential as communication/coordination tools and may help different disciplines such as cognitive systems and systems engineering work together. They may help users, customers, and developers share knowledge (although see Freeman, 2004 for contrary findings). They may contribute to the general avoidance of the team coordination problems that often plague systems development (e.g., Bush, 1997; Richey, n.d.). Another possible role for Concept Maps lies in the management of the significant amounts of information and knowledge that system development teams generate and use. These and other uses of Concept Maps as tools that help systems development teams will be explored as we shape and evolve the Joint Systems Engineering Method.

5 Summary

Large-scale software projects often fail to meet expectations because practitioners are not provided with the technologies that they need to perform their work effectively. Spiral and Waterfall modeling (and their variants) are often used to frame system development efforts, but subsequently end up as mere cover stories. In addition, “user involvement” in the design process is usually too little and too late. We conducted a cognitive task analysis to seek a

more detailed understanding of the reasons for the high rate of systems development failure. We conducted a documentation analysis of about 50 sources (journal articles, books, book chapters, government documents, systems engineering standards, and website content) describing systems and software engineering methods and tools, and system development and acquisition processes. This analysis highlighted some limitations in systems development. Using a variant of the Critical Decision Method, we conducted in-depth interviews with six individuals having at least 20 years of experience in software engineering, including experience as managers of large-scale procurement projects. The data were represented in two ways. One was in the form of timelines showing when in the procurement and system development process activities are performed and where some new form of support tool might be useful to program stakeholders. We also represented the results in the form of Concept Maps. These were created to summarize results concerning problems and issues in the government procurement process. They make clear the challenges that confront all of stakeholders in the procurement process, and therefore are suggestive of how the system development process might be better managed. At the same time, Concept Maps might facilitate the integration of human-centering considerations as primary to insuring that systems are usable and useful.

6 Acknowledgement

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7 References

Boehm, B. (1988). A spiral model of software development and enhancement. *Computer*, *21*, 61-62.

Brooks, F.P. (1995). *The mythical man-month*. Boston, MA: Addison-Wesley.

Bush, M. (1997). NIMROD case study. Retrieved 14 June 2006 from http://www.scism.sbu.ac.uk/~bushm/units/NIMROD_Case_Study.html.

Cannon-Bowers, J. A., & Salas, E. (1998). *Making decisions under stress: Implications for individual and team training*. Washington DC: American Psychological Association.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Coyle, P.E. (1999, May). *Simulation based acquisition for information technology*. Paper presented at the 1999 Academia, Industry, Government Crosstalk Conference, Washington, DC.

Davenport, T.H. (1998). Putting the enterprise into the enterprise system. *Harvard Business Review*, July-August, pp. 1-10.

Department of Defense (2004). "Department of Defense Architecture Framework Version 1.0, Vol. 1: Definitions and Guidelines." Washington, DC: Department of Defense.

Department of Defense (2003). "Department of Defense Instruction 5000.2: Operation of the Defense Acquisition System." Washington, DC: Department of Defense.

Department of Defense (1996). "Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems Acquisition Programs." Instructions 5000.2-R. Washington, DC: Department of Defense.

Eggen, D. (June 6, 2005). FBI pushed ahead with troubled software. Retrieved 14 June 2006 from *Washingtonpost.com*.

Freeman, L.A. (2004). The effects of concept maps on requirements elicitation and system models during information systems development. In A. Cañas, J. D. Novak, & F. M. González (Eds.), *Proceedings of the First International Conference on Concept Mapping: Concept Maps: Theory, Methodology, Technology* (pp. 257-264). Navarra, Spain: Pública de Navarra.

Gaitros, D.A. (March 2004). Common errors in large software development projects. Crosstalk. Retrieved 14 June 2006 from http://www.stsc.hill.af.mil/crosstalk/2004/03/0403Gaitros.html.

Hoffman, R. R., Ford, K. M., & Coffey, J. W. (2000). *The Handbook of Human-Centered Computing* (Deliverable on the Contract, *Human-Centered System Prototype*). National Technology Alliance. Retrieved 14 June 2006 from http://ihmc.us/research/projects/EssaysOnHCC/

Hoffman, R.R., Coffey, J.W., Carnot, M.J., & Novak, J.D. (2002). An empirical comparison of methods for eliciting and modeling expert knowledge. *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting*. Santa Monica, CA: Human Factors and Ergonomics Society.

Hoffman, R. R., Crandall, B., & Shadbolt, N. (1998). Use of the critical decision method to elicit expert knowledge: A case study in the method of cognitive task analysis. *Human Factors*, *40*, 254-276.

Hoffman, R. R., & Elm, W. C. (2006, January/February) HCC implications for the procurement process. *IEEE: Intelligent Systems*, pp. 74-81.

Hoffman, R. R., Roesler, A., & Moon, B. M. (July/August 2004). What is design in the context of Human-Centered Computing? *IEEE: Intelligent Systems*, pp. 89-95.

Klein, G., Ross, K. G., Moon, B. M., Klein, D. E., Hoffman, R. R., & Hollnagel, E. (May/June 2003). Macrocognition. *IEEE Intelligent Systems*, pp. 81-85.

Koopman, P., & Hoffman, R. R., (November/December 2003). Work-arounds, make-work, and kluges. *IEEE: Intelligent Systems*, pp. 70-75.

Leishman, T. R., & Cook, D. A. (2002, Apr). Requirements Risks Can Drown Software Projects. *Crosstalk, 15,* 4-8.

Marketplace. (1997, January). *Marketplace for January 31st, 1997*. National Public Radio.

McConnell, S. (1996). *Rapid development: Taming wild software schedules*. Redmond Washington: Microsoft Press.

Nah, F.F., Lau, J.L., & Kuang, J. (2001). Critical factors for successful implementation of enterprise systems. *Business Process Management Journal*, *7*, 285-296.

Nuseibeh, B. (2001). Weaving together requirements and architecture, *IEEE Computer, 34,* 115-117.

Richey, G.K. (n.d.). "F-111 systems engineering case study." Air Force Center for Systems Engineering. Retrieved 14 June 2006 from http://cse.afit.edu/page.cfm?page=49

Whittaker, B. (1999). What went wrong? Unsuccessful information technology projects. *Information Management and Computer Security, 7*, 23-29.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
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USING VISUAL CONCEPT MAPPING TO COMMUNICATE MEDICATION INFORMATION TO PATIENTS WITH LOW HEALTH LITERACY; A PRELIMINARY STUDY

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Abstract. Visual concept maps, used in conjunction with verbal patient counseling, may be useful to communicate critical medication information, assist patients with remembering medication instructions, and thereby improve low literate patients' medication adherence and health outcomes. Numerous researchers have stressed the importance of rigorous pre-testing before implementing the use of a visual tool with patients. This exploratory study represents the first pre-test of medication concept maps with first-year pharmacy students. Three concept maps were pre-tested for two chronic disease states: diabetes and asthma. These disease states were selected because the link between low literacy and poor health outcomes has been well established in relationship to them. All three concept maps were interpreted correctly by a majority of students at a rate that exceeded the American National Standards Institute mandate of a minimum of 85%, thereby indicating that the visual concept maps have potential as a communication tool. Students' provided feedback that will be used to improve the concept maps in preparation for pre-testing them with an audience of low literate adults and then later with patients. (175 words)

1 Introduction

It is hypothesized that using visual concept maps will aid low-literate patients in understanding and remembering how to take their medications. Using a limited amount of words, the concept map can describe how and when to take medication(s) on a daily schedule. An individualized medication concept map, in conjunction with patient counseling, may be a tool that could be used to communicate critical medication information to low literate patients. The potential exists that an individualized medication concept map may increase patient medication adherence and consequently improve patient health.

2 Background

Low functional health literacy has been found to be an independent predictor of medication nonadherence, meaning that patients do not take their medications as prescribed thereby leading to poor health outcomes (Dimateo, 2004). Health literacy, often defined as the ability to read, understand, and act on health care information, entails the ability to perform basic reading and numeric tasks in the health care context including comprehending prescription labels, appointment slips, insurance forms, and other health-related information (Schillinger et al., 2003; Kirsch et al., 1993). An expanded model of health literacy was proposed by Zarcodoolas, Pleasant & Greer (2005) in which the concept refers to a "wide range of skills, and competencies that people develop to seek out, comprehend, evaluate and use health information and concepts to make informed choices, reduce health risks, and increase quality of life" (p. 196). The prevalence of inadequate functional literacy has been well documented, and it is estimated that as many as 44 million people in the United States have only rudimentary literacy skills and another 50 million have marginal literacy skills (Kirsch et al., 1993; National Work Group on Literacy and Health, 1998; Youmans & Schillinger, 2003). Recently released preliminary results of the 2003 National Assessment of Adult Literacy indicate that the average quantitative literacy scores of adults increased only slightly between 1992 and 2003, while the average prose and document literacy did not change significantly (Kutner, Greenberg & Baer, 2005). Similar lack of change was found in the adult literacy and life skills study in canada (Raising the Score) in which 42% of the population was found to have literacy levels that are below those needed for success in today's society. Low literacy is prevalent worldwide. In year 2000, 20% of adults over 15 were illiterate, meaning "there were about 860 million illiterate adults in the world. . . . [and] over 100 million children have no access to school, and countless children, youth and adults who attend school or other education programmes fall short of the required level to be considered literate in today's complex world" (UNESCO). The percentage of the United Kingdom population with low literacy is similar to the U.S., closely followed by Canada, while the Netherlands and Sweden have recorded somewhat lower numbers (Houts et al., 2001). Although health literacy can affect all social classes, it more commonly affects elderly, low income, poor, and minority patients. Low literate patients with chronic physical and mental diseases have been found to be less likely to improve their health (Youmans & Schillinger, 2003).

People with low health literacy will have difficulty learning information from many written patient medical materials, including medication labels. There are many reasons why a patient may choose not to follow medication instructions (Dimateo, 2004; Hanson & Hartzema, 1995), but some patients do not understand how to take their medications because they are unable to read the instructions, or in the case of multiple medications, remember them (Youmans & Schillinger, 2003; Baker et al., 1996; Gazmararian, Williams, Peel & Baker, 2003; Williams, Baker, Parker, & Nurss, 1998). Research has demonstrated that patients with low health literacy have difficulty with basic medication instructions. One study found that of 2,659 hospital patients, most of whom had low health literacy, 42% gave incorrect explanations regarding taking medication on an empty stomach, 26% for when the next appointment is scheduled, and 60% had difficulty with a standard consent form (Williams et al., 1998). Low health literacy can impair communication about the risks and benefits of treatment options (Davis et al., 2002) which is especially critical in the management of chronic diseases because patients "typically must cope with complex treatment regimens, manage visits to multiple clinicians, monitor themselves for changes in health status, and initiate positive health behaviors" (Schillinger et al., 2003, p. 84). Patients with low literacy have more difficulty naming their medications and may hold health beliefs that can interfere with adherence (Schillinger et al., 2003).

Research has shown that visual aids can increase a patient's understanding of their medication regimen(s) (Ngoh & Shepherd, 1997). Visuals accompanied by oral instructions have increased patients' recall more than if they are given oral instructions alone (Houts et al., 2001). Sojourner and Wogalter (1998) provided evidence that information provided in a redundant form, using pictures and text, helps patients in recalling information because the formation of the message is encoded in multiple places in memory. With difficult reading materials, patients may take the information out of context, skip over words, and become easily tired and frustrated (Doak, Doak, & Meade, 2002). Dowse and Ehlers (1998) noted that patients preferred medical information sheets with pictures that illustrate the text. Pictures stimulate interest and add meaning to written text (Houts et al., 2001). Patients prefer attractive simple materials and instructional graphics can increase comprehension of medical information (Andrus & Roth, 2002). General benefits of using visuals are being able to cross age and language boundaries and convey information quickly without relying solely on verbal communications (Moriyama, Harnisch, & Matsubara, 1994).

The use of visual concept maps may have potential to enhance patients' understanding of medication regimen(s). Visual concept maps can incorporate meaningful pictograms to diagram a flow or hierarchy of ideas. As a graphic knowledge representation tool, a concept map diagrams key ideas in a topic area and demonstrates the relationships among them (Novak, 1998; Hill, 2004). They provide written, visual, and spatial information and this combination is more likely to be retrievable from memory than written information alone (Robinson, Robinson, & Katayama, 1999). An individualized concept map detailing a medication regimen may be a tool that could be used to communicate critical medication information to low literate patients. Concept maps, used in conjunction with verbal patient counseling and written medication instructions, may further patients' understanding of their medication regimens and therefore potentially improve their medication adherence and health outcomes. One possible advantage of a concept map is that it is a portable tool that patients can carry with them.

This study represents a preliminary exploration of the efficacy of using concept maps for communicating medication treatment information to low literate patients with chronic disease(s). According to the American Nationals Standards Institute, more than 85% of people should interpret a visual correctly for it to be considered effective (American National Standards Institute, 1991). Many pictograms have failed in transmitting a message successfully because they have not been well designed or appropriately tested (Sojourner & Wogalter, 1998; Moriyama, Harnisch, & Matsubara, 1994). Numerous researchers have stressed the importance of rigorous pre-testing before implementing the use of a visual tool with patients (Ngoh & Shepherd, 1997; Houts et al., 2001; Sojourner & Wogalter, 1998; Doak, Doak, & Meade, 2002). The purpose of this study is to pre-test visual concept maps with first-year pharmacy students to determine if they are able to interpret them correctly. These students were selected because they have not yet studied pharmacotherapy and therefore were roughly analogous to patients in their knowledge of the selected disease states, and were less influenced by their existing knowledge of asthma and diabetes medication regimens than students who are further advanced in the curriculum. Performing this pre-test is the first of several pre-tests planned for this research. The researcher will use the information garnered from this preliminary research project to improve the concept maps before advancing to the next stage of pre-testing with adults at a literacy center, and then eventually with patients.

3 Methods

Three concept maps were developed for two chronic disease states: diabetes and asthma. These disease states were selected because the link between low literacy and poor health outcomes has been well established in relationship to them (Gazmararian, Williams, Peel, & Baker, 2003; Berkman et al., 2004; Paasche-Orlow et al., 2005). Patients with these diseases need to master self-care techniques, know how to take appropriate action in crisis situations, and in the case of asthma differentiate when to take maintenance and rescue medications. The concept maps were created in Inspiration 7.0 software. Symbols used were either selected from those available in the software or they were found on the Internet through a Google image search. Images of medications were accessed via the Medmaster website that contains actual photographs of the medications. The image used to indicate inhaler use is one of 23 USP-DI pharmaceutical pictograms. The concept maps rely primarily on pictorial information including photographs of the actual medications, while written information was kept to a minimum. This deviates from typical concept map structure in that the use of linking words has been minimized in order to reduce reliance on written words. Another deviation is that these concept maps lack a hierarchical structure (Novak, 1998) because the intent is to diagram the process of taking medications throughout the day rather than to diagram the relative importance of concepts in relationship to each other. The concept maps have been reviewed by several clinical pharmacy faculty and found to be accurate in illustrating the respective medication regimens. These maps are meant to be used in conjunction with verbal patient counseling to improve patients' recall of medication instructions.

The concepts maps were formulated following suggestions for using visual illustrations found in a literature search. Briefly, these include designing simple, realistic pictures with limited content, using familiar objects and symbols, using caution in the use of abstract symbols, and using background space appropriately (Ngoh & Shepherd, 1997; Houts et al., 2001; Sojourner & Wogalter, 1998; Doak, Doak, & Meade, 2002; Moriyama, Harnisch, & Matsubara, 1994). Visual concept maps should be thoroughly pre-tested with the target audience, however, the idea of using concept maps in healthcare is preliminary and the researchers believes they should be first tested with a non-patient audience to determine if they will be interpreted correctly prior to pre-testing them with patients.

A research protocol was approved by the Virginia Commonwealth University Institutional Review Board (IRB) to pre-test the use of the template concept maps with a convenience sample of a class of first-year pharmacy students in Fall 2005. The efficacy of using concept maps for communicating medical information was determined by tracking whether students' were able to accurately interpret the medication regimen described pictorially on the concept map. The concept maps were described as illustrations in the pre-testing so as not to confuse the issue by discussing concept maps.

The pretest consisted of asking students about their interpretations and perceptions of three visual concept maps that illustrate medication regimens for diabetes (Figure One and Two) and asthma (Figure Three). The medication directions, or Sig, were deliberately omitted so that students would not be led in their interpretations. Students answered three questions for each concept map: 1) how they interpreted the directions for taking the medication(s), 2) whether they were confused by anything in the concept map, and 3) what they thought should be changed, added, or subtracted. Following these, students were asked whether they believed concept maps would be a helpful method in communicating medication information, to explain their reasons why, and to add any other comments they might have. Finally, students were asked if they were asthmatic or diabetic to determine how many students had detailed prior knowledge of the disease states and the relevant medications.

These questions were contained on a four-page interpretation form. No personal identifiers were collected and students were instructed not to write their name on the form. Following University Institutional Review Board requirements, an explanatory cover page was attached to the Interpretation Form that detailed the purpose of the study, a description of the study and student involvement, risks and discomforts, benefits, costs, alternatives, voluntary participation and withdrawal, and information regarding to whom questions should be directed.

This exercise was conducted in a pharmacy communications course in the first year of a Doctor of Pharmacy program at Virginia Commonwealth University. The class session was devoted to explaining the use of visual aids to communicate health information to patients. Class began with a 5-minute introduction regarding what pharmacists are currently doing to aid patients with low health literacy. Distribution of the Interpretation Form was accompanied by explanation of the reasons for the study and directions for completing the Interpretation Form. Students were instructed that their responses would not affect their grades in the course, that their participation was voluntary and

that they were able stop their participation at any time. Students took approximately 10 minutes to complete the form. After the forms were collected, class was resumed with a presentation devoted to the idea of using visuals to communicate medical information.

There were 106 first-year Doctor of Pharmacy students enrolled in the communications course in Fall 2005, and 86 students participated in the study. Students admitted to the Doctor of Pharmacy degree program at this university must have completed a minimum of 68 hours of prerequisite courses including biology, chemistry, physics, organic chemistry, mathematics, public speaking, and English. Demographic information collected by the dean's office indicated that fifty-five percent of the students had completed prior degrees, primarily in chemistry, biology, and biochemistry. Sixty-seven percent of the students were female and 33% male. The median age of the class was 24 years (range 19 – 39). Sixty-seven percent of the students were Caucasian, 18% Asian-American, 7.2% African-American, and 4.5% other. The latter category includes students who do not identify with the aforementioned categories and international students. Information collected by the course instructor indicated that approximately half of the students had some pharmacy work experience.

4 Results

The first concept map portrays the use of 1 tablet of Glucophage 500 mg to be taken twice a day with meals and 1 tablet of Ditropan XL 5 mg. to be taken at bedtime (Figure 1). Of the students participating, 83 (96.5%) correctly interpreted the medication instructions. One more came close but his/her description was not specific about which medication was to taken at breakfast, dinner, and bedtime. However, students had several questions. For example, 34 students (39%) wanted to know about whether Glucophage should be taken before, during or after meals, another four (4.6%) were concerned about whether it should be taken at a certain time before consuming food, and two (2.3%) were unclear about whether Glucophage should be taken with or without food. Seven students (8%) were uncertain about how many tablets should be taken. Several were concerned about symbols they found confusing. Four (4.6%) felt that the sun symbol being the same at morning, noon, and evening was unclear, and the symbol for food was also unclear to one (1.1 %) student. One (1.1 %) student felt that the arrow from breakfast to lunch was confusing, and five (5.8%) indicated that including a lunch sign when no medication was to be taken during lunch was misleading. Four (4.6%) students asked about patients who work odd hours, and another wanted to know what would happen if a patient skips a meal. One (1.1%) felt that the illustration was too cluttered.

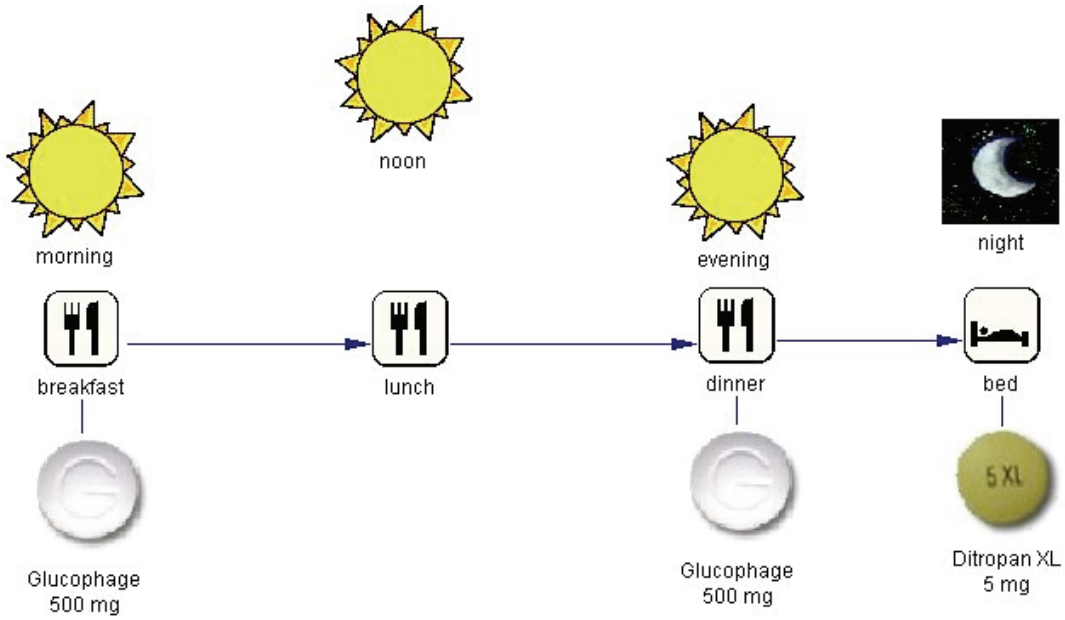


Figure One: Concept Map Illustrating the Use of Glucophage and Ditropan

Suggestions students had for improvement of Figure One included clarification for when the medications were to be taken. Twenty students (23%) suggested incorporation of an indication about whether Glucophage should be

taken before, during, or after a meal. Six (6.9%) students thought that lunch should be omitted from the picture and that the medicine names should be in a larger font size so the patient can see the medications better. Eight (9.3%) thought that the patient would need an indication of the number of tablets to be taken. Eight (9.3%) students wanted the illustration to indicate the number of tablets to be taken, and one suggested the use of color to help patients distinguish the medications. One (1.1%) wanted clarification regarded whether the medications were to be taken with or without food. Three (3.4%) students reiterated their concerns with the visual images for the sun, and felt they should be eliminated, while making the name of the drug and dosage stand out more. One (1.1%) felt that the size of the sun should be reduced because it was distracting. Six (6.9%) expressed the need for better images, and two suggested the addition of a few more words. Two students (2.2%) wanted a clear indication that the medication should be taken orally, and three (3.4%) wanted to see a clear differentiation made between morning and evening. One (1.1%) repeated his/her concern for the person working shifts who would need his/her medication regimen adjusted to suit his/her schedule. Thirty-seven (43%) made no comments.

Figure Two illustrates the use of insulin for treatment of diabetes. Eighty-four (97.6%) students correctly interpreted the concept map, while one misinterpreted the time of the dinner injection and one thought there should be three injections at bedtime which is not indicated in the illustration. When asked what, if anything, was confusing about the illustration, 30 students (34.8%) asked how much insulin should be injected, two (2.3%) wanted to know whether patients should test their sugar before or after injecting the insulin and one (1.1%) was concerned about how injections should be scheduled in relationship to snacks. Two (2.3%) thought that pictures of the sun were confusing and one (1.1%) suggested that pictures of lunch and bedtime should be eliminated since no injections were scheduled for those times. Forty-eight (55.8%) students made no comment. Thirty students (34.8%) had no suggestions for change, but 36 (41.8%) asked how much insulin should be injected, and four (4.6%) asked about where the medication should be injected, presumably referring to a body location. Two students (2.2%) suggested that the lunch and bedtime pictures should be removed, and three (3.4%) thought a clock should be used to indicate time. One (1.1%) thought the type was small and another (1.1%) felt that the text indicating that the medication should be taken "15 minutes before a meal" should be in bold. Again, one (1.1%) student stated his/her concern for how the medication protocol should be altered to accommodate a patient working night shifts.

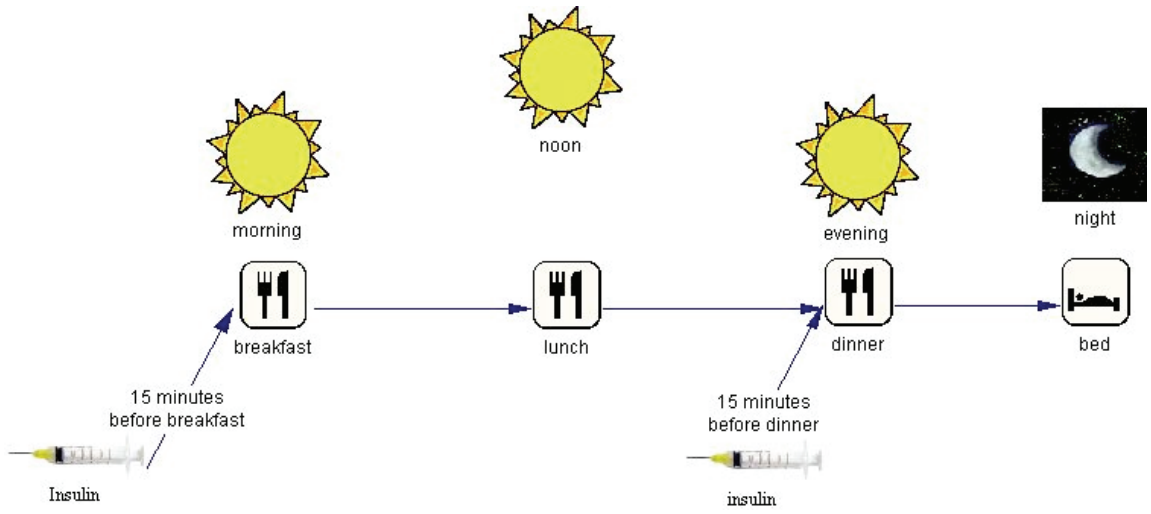


Figure Two: Concept Map Illustrating the Use of Insulin for Treatment of Diabetes

The third concept map illustrates the use of Albuterol as a rescue for treatment of asthma, in which a patient is to take two puffs with a one-minute interval between puffs, wait 20-minutes before repeating, and wait 20 minutes before repeating once more. If the treatment is not effective the patient is to call his/her physician before proceeding to the emergency room. Eighty-three students (96.5%) interpreted the concept map correctly while two (2.2%) were close but missed the necessity of using two puffs of Albuterol at each administration, and one (1.1%) stated simply that he/she was confused. Twenty-six (30.2%) students thought that stacking two pictograms one above the other was confusing, while another (1.1%) felt that that the USPDI pictogram looks like the patient is drinking the medication rather than inhaling medicated mist as the pictogram is intended to portray. Fourteen students (16.2%)

felt that the illustration contained too many pictures and arrows, and one (1.1%) thought that two arrows at each junction could be confusing. Fourteen students (16.2%) asked how many puffs of Albuterol should be taken. Three (3.4%) wanted to know why the doctor should be called prior to proceeding to the emergency room, and one (1.1%) asked about what to do if the doctor proves unavailable. Five students (5.8%) wanted to know how long a patient should wait after the third administration of Albuterol before calling the doctor. One (1.1%) asked whether relief would be instantaneous or would take 20 minutes. Twenty-nine students (33.7%) had no comment.

Figure Three was the most complex concept map, and when asked for suggestions for improvement, seven (8.1%) suggested the illustration should be simplified and contain less clutter and two (2.3%) students suggested that better pictures needed to be used. Four (4.6%) indicated that the part about calling the doctor and going to the emergency room needed clarification, and one (1.1%) suggested adding the emergency room's and doctor's phone numbers. The use of two puffs of Albuterol with a one-minute interval at each administration caused some concern. One student (1.1%) suggested using only one pictogram of inhaler use at each administration, and another (1.1%) wanted the two pictograms to be placed side by side with a plus sign to indicate two puffs, and still another (1.1%) suggested substituting the second pictogram with the words 'use two sprays.' Two students (2.3%) suggested the illustration should be clarified, two (2.3%) wanted more information to be added, two (2.3%) more thought the illustration should be more informative, and one (1.1%) thought the illustration should be larger. One student (1.1%) indicated that broken arrows instead of solid arrows should be used, and another (1.1%) believed that the addition of clock faces would be helpful. Finally, one student (1.1%) suggested that the word asthma instead of shortness of breath should be used. Thirty-five students (40.7%) made no suggestion.

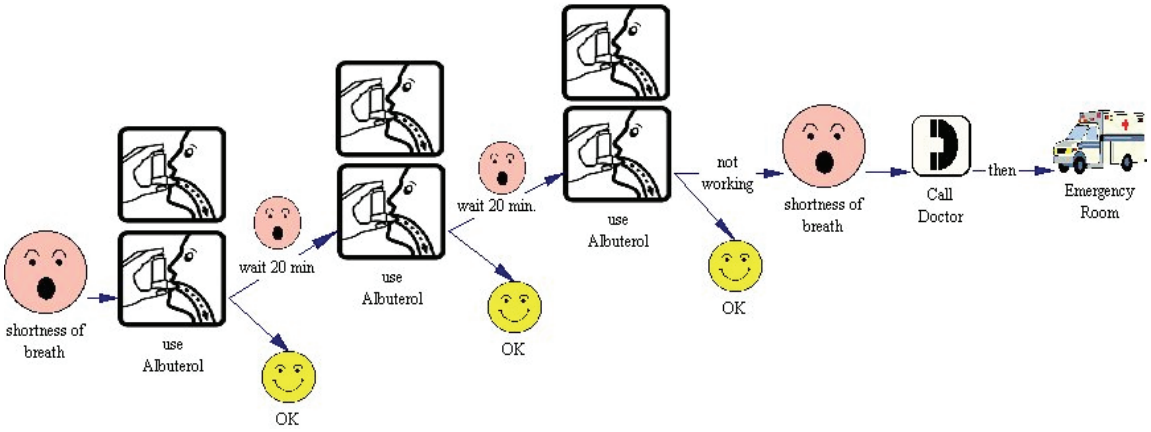


Figure Three: Concept Map Illustrating Rescue Medication Used to Treat Asthma

Few students made general comments about the use of concept maps for communicating medical information. Nine (10.4%) students felt that the visual concept maps were a good idea and that they would not be difficult to implement, while two (2.3%) suggested that the concept maps needed to be more descriptive and clear. For example, two (2.3%) students thought that the amount of medication and the times it should be taken needed to be included. Two (2.3%) felt that the diagrams could be made pocket-sized so that patients could carry the illustrations with them. Two (2.3%) suggested that graphic designs are good for people who cannot read, and another (1.1%) felt that visual concept maps provided patients with a 'play by play of what their day should be like' in relationship to their medication. At the same time, three (3.4%) students cautioned that the illustrations could cause more confusion especially if steps are missing or not labeled clearly. One (1.1%) suggested that the illustrations could add another layer of complexity. However, another (1.1%) student suggested that the visual concept maps could also be used with patients who read well because it offers an alternate way of understanding directions that some might find more convenient. Only one (1.1%) student had diabetes, while four (4.6%) had experience with asthma but only two (2.3%) had active cases.

5 Conclusions

All three concept maps were interpreted correctly by a majority of students at a rate that exceeded the American National Standards Institute's (1991) mandate of a minimum of 85%, thereby indicating that the visual concept

maps have potential as a communication tool. Nevertheless, a limitation of this study is that the pharmacy students selected for the first pre-test of the visual concept maps had reason to be interested in medications even if they have yet to learn in more detail about the two disease states of interest in this study. Given the mean age of the students it can be expected that they would have a high degree of visual literacy because of exposure to computers and video games. It appears that only a few had personal experience with the disease states, and thus most lacked detailed knowledge of the relevant medications. Some interesting responses were garnered from students that can be used to inform revisions of the visual concept maps before pre-testing them with a focus group of low literate adults and then with patients.

The variety of students' responses emphasize that there are many ways that individuals can interpret visual concept maps, or any pictorial image intended to communicate medication information. It appears that a few more words could be used to clarify the timing and dosage of medication administration, and larger font used for the limited number of words employed. Better symbols for indicating the time of day need to be found or created before further pre-testing. Students' responses indicate a need for parsimony in the concept maps as they appeared to dislike what they regarded as visual clutter. Students' concern for patients who work unusual hours verifies the researchers' original intention that the concept maps be tailored to individual patient's schedules and needs. Finally, the variety of students' interpretations and recommendations confirms what the literature indicates that visuals should not be used without being accompanied by verbal patient counseling performed by a knowledgeable health professional. The results of this study indicate that a visual concept map may have potential as a useful supplement to patient counseling and written medication instructions. Further pre-testing, incorporating the suggestions garnered in this study, will take place with adult students in a literacy program before proceeding to testing with low literate patients with the disease states of interest.

6 References

American National Standards Institute. (1991). *Accredited standard on safety colours, signs, symbols, labels, and tags*. Z535.1-5. Washington DC: National Electrical Manufacturers Association.

Andrus, M. R., & Roth, M. T. (2002). Health literacy: A review. *Pharmacotherapy, 22,* 282-302.

Baker, D. W., Parker, R. M., Williams, M. V., Pitkin, K., Parikh, N. S., Coates, W., & Imara, M. (1996). The health care experience of patients with low literacy. *Archives of Family Medicine, 5*, 329-334.

Berkman, N. D., Dewalt, D. A., Pignone, M. P., Sheridan, S. L., Lohr, K. N., Lux, L., Sutton, S. F., Swinson, T., & Bonito, A. J. (2004). *Literacy and health outcomes*. Summary, Evidence Report/Technology Assessment No. 87. Rockville MD: AHRQ Publication No. 04-E007-1.

Davis, T. C., Williams, M. V., Marin, E., Parker, R. M., & Glass, J. (2002). Health literacy and cancer communication. *CA: A Cancer Journal for Clinicians, 52*, 134-149.

Dimateo, M. R. (2004). Variations in patients' adherence to medical recommendations: A quantitative review of 50 years of research. *Medical Care*, *42,* 200-209.

Doak, L. G., Doak, C. C., & Meade, C. D. (2002). Strategies to improve cancer education materials. *Oncology Nursing Forum, 23,* 1305-1312.

Dowse, R., & Ehlers, M. S. (1998). Pictograms in pharmacy. *The International Journal of Pharmacy Practice, 6,* 109-118.

Gazmararian, J. A., Williams, M. V., Peel, J., & Baker, D. W. (2003). Health literacy and knowledge of chronic disease. *Patient Education and Counseling, 51*, 267-275.

Hanson, E. C., & Hartzema, A. (1995). Evaluating pictograms as an aid for counseling elderly and low-literate patients. *Journal of PharmaceuticalMarketing Management, 9,* 41-54.

Healthy People 2010. Retrieved February 20, 2006, from http://www.cdc.gov/nchs/about/otheract/hpdata2010/abouthp.htm

Hill, L. H. (2004). Concept mapping in a pharmacy communications course to encourage meaningful student learning. *American Journal of PharmaceuticalEducation, 68*(5), Article 109.

Houts, P. S., Witmer, J. T., Egeth, H. E., Loscalzo, M. J., & Zabora, J. R. (2001). Using pictographs to enhance recall of spoken medical illustrations. *Patient Education and Counseling, 43*, 231-242.

Kirsch, I,, Jungeblut, A., Jenkins, L., & Kolstad, A. (1993). *Adult literacy in America: A first look at the findings of the national adult literacy survey.* Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Kutner, M., Greenberg, E., & Baer. J. (2005). A first look at the literacy of America's adults in the 21st century. Retrieved February 13, 2006, from http://nces.ed.gov/NAAL/PDF/2006470.PDF

Moriyama, M., Harnisch, D. L., & Matsubara, S. (1994). The development of graphic symbols for medical symptoms to facilitate communication between health care providers and receivers. *Tohoku Journal of Experimental Medicine, 174*, 387-398.

The National Work Group on Literacy and Health. (1998). Communicating with patients who have limited literacy skills. *Journal of Family Practice, 46*, 168-175.

Ngoh, L. N., & Shepherd, M. D. (1997). Design, development, and evaluation of visuals aids for communicating prescription drug instructions to nonliterate patients in rural cameroon. *Patient Education and Counseling, 30*, 257-270.

Novak JD. (1998). *Learning, creating and using knowledge: Concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Lawrence Erlbaum & Associates..

Paasche-Orlow, M. K., Riekert, K. A., Bilderback, A., Chanmugam, A. P., Rand, C. S., Brancati, F. L., & Krishnan, J. A. (2005). Tailored education may reduce health literacy disparities in asthma self-management. *American Journal of Respiratory and Critical Care Medicine,* 172, 980-986.

Raising the score: Promoting adult literacy in Canada. Retrieved March 10, 2006, from http://www.ccl-cca.ca/CCL/Reports/LessonsInLearning/LIL-29Sep2005.htm

Robinson, D. H., Robinson, S. L., & Katayama, A. D. (1999). When words are represented in memory like pictures: Evidence of spatial coding of study materials. *Contemporary Education Psychology,* 163, 83-90.

Schillinger, D., Piette, J., Grumbach, K., Wang, F., Wilson, C., Daher, C., Leong-Grotz, K., Castro, C., & Bindman, A. B. (2003). Closing the loop: Physician communication with diabetic patients who have low health literacy. *Archives of Internal Medicine*, 163, 83-90.

Sojourner, R. J., & Wogalter, M. S. (1998). The influence of pictorials in the comprehension and recall of pharmaceutical safety and warning information. *InternationalJournal of Cognitive Ergonomics, 2,* 93-106.

UNESCO. Meeting the major global challenge of literacy for all. Retrieved 9 June 2006, from http://portal.unesco.org/education/en/ev.php-URL_ID=5000&URL_DO=DO_TOPIC&URL_SECTION=201.html

Williams, M. V., Baker, D. W., Parker, R. M., & Nurss, J. R. (1998). Relationship of functional health literacy to patients' knowledge of their chronic disease: A study of patients with hypertension and diabetes. *Archives of Internal Medicine, 158*, 166–172.

Youmans, S. L., & Schillinger, D. (2003). Functional health literacy and medication use: The pharmacist's role. *Annals of Pharmacotherapy, 37*, 1726-1729.

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Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

UTILIZACIÓN DE MAPAS CONCEPTUALES PARA MEJORAR LOS CONOCIMIENTOS RELATIVOS A LA CORRIENTE ELÉCTRICA CONTINUA MEDIANTE SU "RECONSTRUCCIÓN COLABORATIVA"

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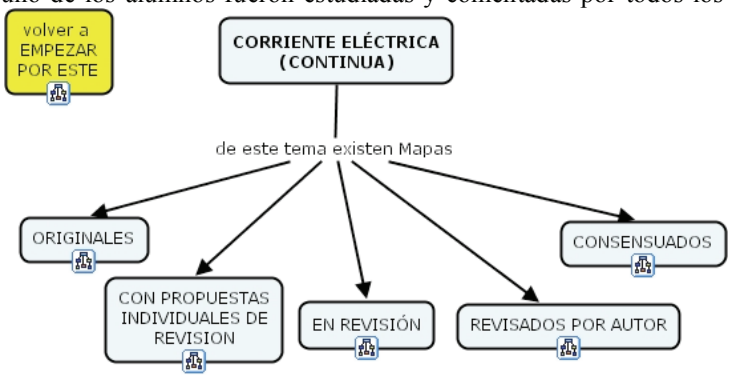
Resumen. Se presenta una experiencia de innovación educativa en la que se ha hecho uso de los mapas conceptuales y, concretamente, del programa informático CmapTools para realizar trabajos colaborativos entre los alumnos como método de ayuda mutua para la **"Reconstrucción Colaborativa"** de los conocimientos sobre la corriente eléctrica. La experiencia se ha llevado a cabo con los alumnos de la asignatura de didáctica de la física, del último ciclo de la licenciatura de ciencias físicas de la universidad de Extremadura (España), durante el curso académico 2004-05 y evaluada un año después.

1 Introducción

Nuestro grupo de investigación viene utilizando desde hace más de 20 años los mapas conceptuales para ayudar a nuestros alumnos a realizar aprendizajes significativos (Pérez, Peña & Mahedero, 1979) y hemos generalizado el concepto de mapa conceptual al de "Mapa de Experto Tridimensional" (Montanero, Pérez & Suero, 1998; Pérez et al., 2001), pero la necesidad de compartir estos mapas en red de manera que permitiera la realización de trabajos colaborativos entre nuestros alumnos de forma fluida nos hizo adoptar los CmapTools (Cañas et al., 2004) como herramienta de trabajo (Pérez et al., 2004). La experiencia presentada se llevó a cabo en la universidad de Extremadura (España) con los alumnos de la asignatura de didáctica de la física del último ciclo de la licenciatura de ciencias física durante el curso escolar 2004/05 y fue evaluada un año después para comprobar en qué grado el aprendizaje retenido a largo plazo había aumentado con la metodología didáctica utilizada.

2 Método

Inicialmente se propuso a cada uno de los alumnos participantes en la experiencia que realizara un mapa conceptual individual en el que reflejara la manera que tenía de relacionar entre sí los conceptos relativos al fenómeno de la corriente eléctrica. Una vez recogidos estos mapas, cada uno de los alumnos revisó los mapas realizados por los demás y le propuso a cada uno de ellos los cambios que consideraba oportunos. Todas estas propuestas de modificación de cada "Mapa Original" de cada uno de los alumnos fueron estudiadas y comentadas por todos los demás y uno de ellos se encargó de resumirlas en un "Mapa en Revisión" que el autor del mapa original en cuestión estudió detenidamente aceptando algunas y rechazando otras y justificando la decisión tomada en cada caso. Como resultado de este proceso se llegó al "Mapa Revisado" de cada uno de los alumnos. Más tarde se encargó a otro alumno la realización de una reorganización general del material elaborado incluyendo vínculos entre los diferentes mapas que facilitaran la comparación entre los contenidos de los mismos y la observación de las modificaciones introducidas, y la realización de un "Mapa Consensuado" en el que se resumiera la parte esencial de los diferentes "Mapas Revisados" de cada uno de los alumnos. Aunque la manera más utilizada para intercambiar estos ficheros y dado que nos veíamos casi a diario en las clases, fue la de hacerlo físicamente mediante intercambios de discos (o en los pen-drives), los alumnos que disponían en su casa de conexión a Internet actuaban directamente en los archivos situados en nuestro Sitio Cmap de la "Universidad de Extremadura (España)" o, si su conexión no era lo suficientemente buena, intercambiaban los archivos a través de la FTP del grupo Orion donde eran situados.

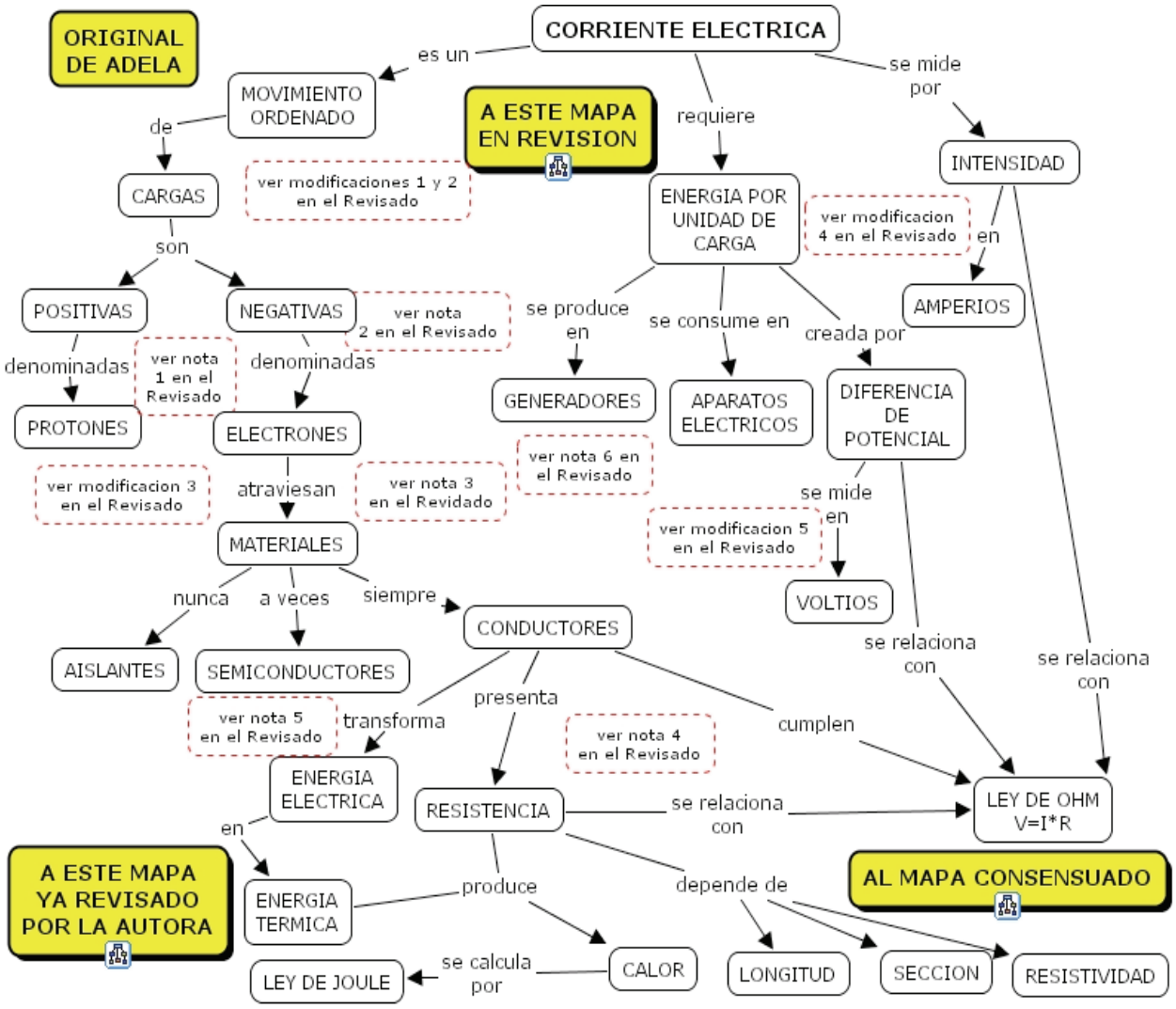


3 Resultados

Los Mapas realizados durante el desarrollo de esta experiencia se encuentran alojados en nuestro sitio Cmap: "Universidad de Extremadura (España)", dentro de la carpeta "Asignatura de Didáctica de la Física" y en la correspondiente al curso 2004/05, donde pueden ser utilizados de manera interactiva mediante la aplicación informática CmapTools. Como ejemplo, a continuación se incluyen 5 de los 65 mapas relativos a la corriente eléctrica elaborados, que resumen el proceso seguido por el mapa que originalmente realizó una de las alumnas participantes en la misma (en este caso concretamente Adela). Para facilitar el seguimiento interactivo del contenido de esta comunicación, estos 5 Mapas que aparecen en la misma, se han situado dentro de la carpeta "Comunicaciones a Congresos" de nuestro sitio Cmap. En estos mapas aparecen vínculos que permiten saltar de unos a otros para poder comparar de manera instantánea las diferencias entre ellos y "notas" que hacen propuestas o aclaran la razón por la que se han aceptado o rechazado las modificaciones propuestas por los compañeros a los mapas originales.

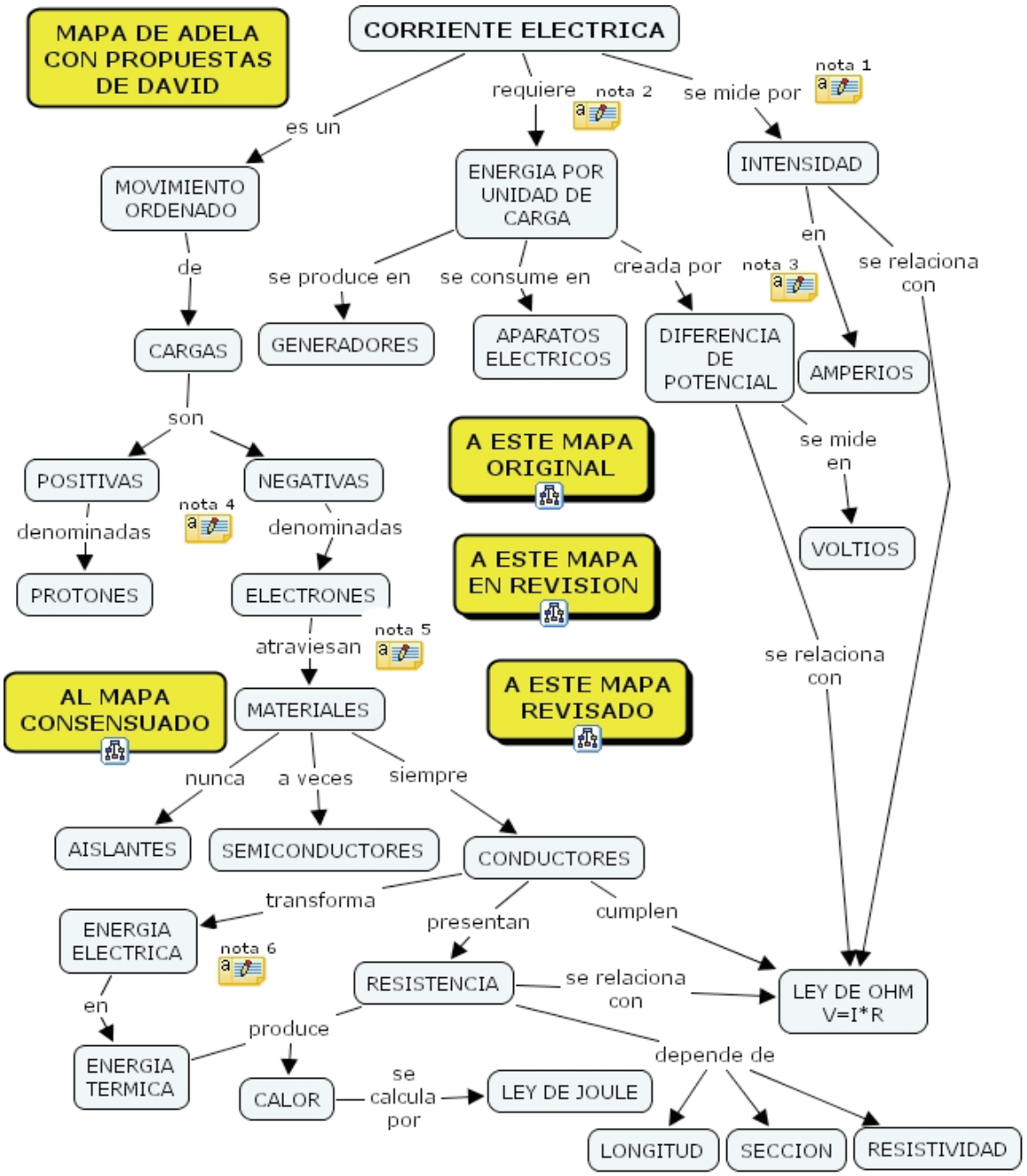
3.1 Mapa Original

Para que desde este primer momento se puedan apreciar las propuestas de modificaciones y aquellas que finalmente fueron asumidas por la autora, se anota en éste qué partes del mismo tiene propuestas de ser modificadas (aunque no han sido aceptadas por la autora) y qué otras partes han sido objeto de propuestas de modificación que finalmente han originado que la autora introduzca una modificación en el mapa revisado.



3.2 Mapa con propuestas individuales de modificación

A continuación se recoge uno de los mapas individuales con las propuestas de modificación de un compañero, en este caso concreto David, (cada uno de los compañeros hizo uno similar) al mapa original de Adela. Como puede observarse en él aparecen 6 Notas que rezan lo siguiente:

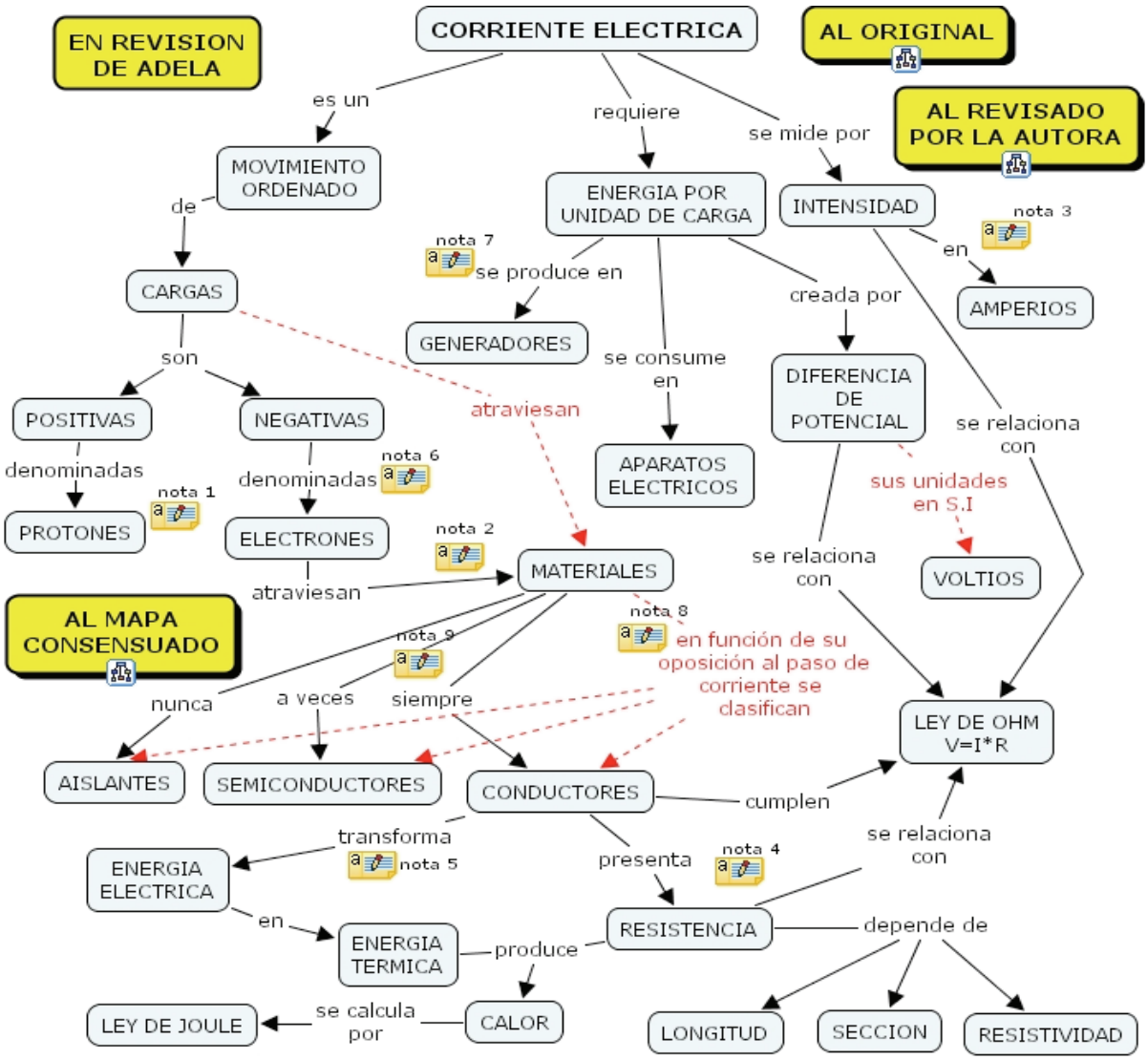


1: pondría "su unidad en el S.I es"
2: pondría "supone" en vez de "requiere"
3: pondría "que circula debido a una"
4: pondría en vez de "denominadas" el nexo "por ejemplo los"
5: quitaría "atraviesan" y pondría "circulan por"
6: pondría que sólo una parte se transforma, no toda

3.3 Mapa "En Revisión"

En este mapa se resumen todas las propuestas de modificación realizadas entre todos sus compañeros al mapa original de Adela. Además de las propuestas concretas con una opción alternativa que aparecen con líneas discontinuas (en rojo en el monitor), existen un total de 9 notas con los comentarios que se reproducen a continuación:

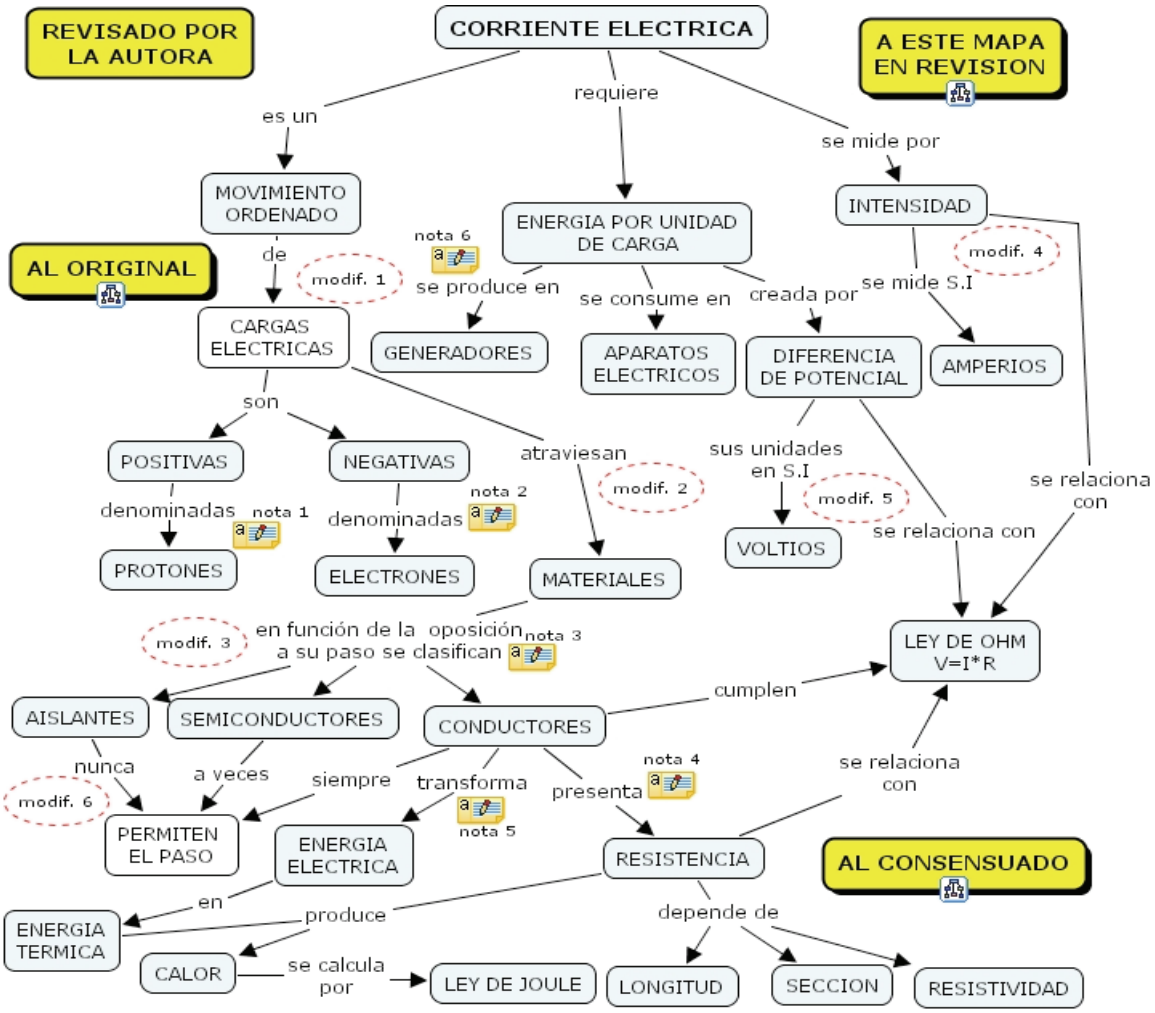
1: los protones no crean corriente eléctrica
2: quitaría atraviesan y pondría "circulan por"
3: diría que en el sistema internacional se mide en
4: los semiconductores y los aislantes también presentan resistencia
5: especifica que sólo se transforma una parte
6: en lugar de denominadas pondría "por ejemplo"
7: ¿no sería mejor poner que lo que se produce en los generadores es la diferencia de potencial?
8: ¿esta clasificación de los materiales no es según la facilidad con que se mueven los electrones?
9: no esta claro



3.4 Mapa Revisado por la autora

Este mapa recoge las modificaciones que ha tenido a bien aceptar la autora del mapa original. Como puede observarse acepta 6 modificaciones que mejoran notablemente su Mapa Original y rechaza las demás. En las diferentes "Notas" aclara el porqué de sus decisiones. Estas 6 notas dicen lo siguiente:

1: Andrea: los protones no crean corriente eléctrica (aceptada y cambio enlace)
2: Mª Loli: En lugar de denominadas pondría "por ejemplo"(Adela: Las cargas eléctricas negativas son únicamente los electrones. No aceptada)
3: José Antonio: ¿Está clasificación de los materiales no es según la facilidad con que se mueven los electrones? Andrea: No esta clara la clasificación (aceptada y cambio enlace).
4: Mariano: Los semiconductores y los aislantes también presentan resistencia. (Adela: Por definición la resistencia es la dificultad que opone un conductor al paso de la corriente eléctrica. No aceptada).
5: David: Especifica que sólo se transforma una parte. (Adela: De esta forma no hay que decir cuanto se transforma. No aceptada).
6: Mariano: ¿no sería mejor poner que lo que se produce en los generadores es la diferencia de potencial? (Adela: Lo pongo así para partir de la energía y no de la diferencia de potencial. No aceptada)

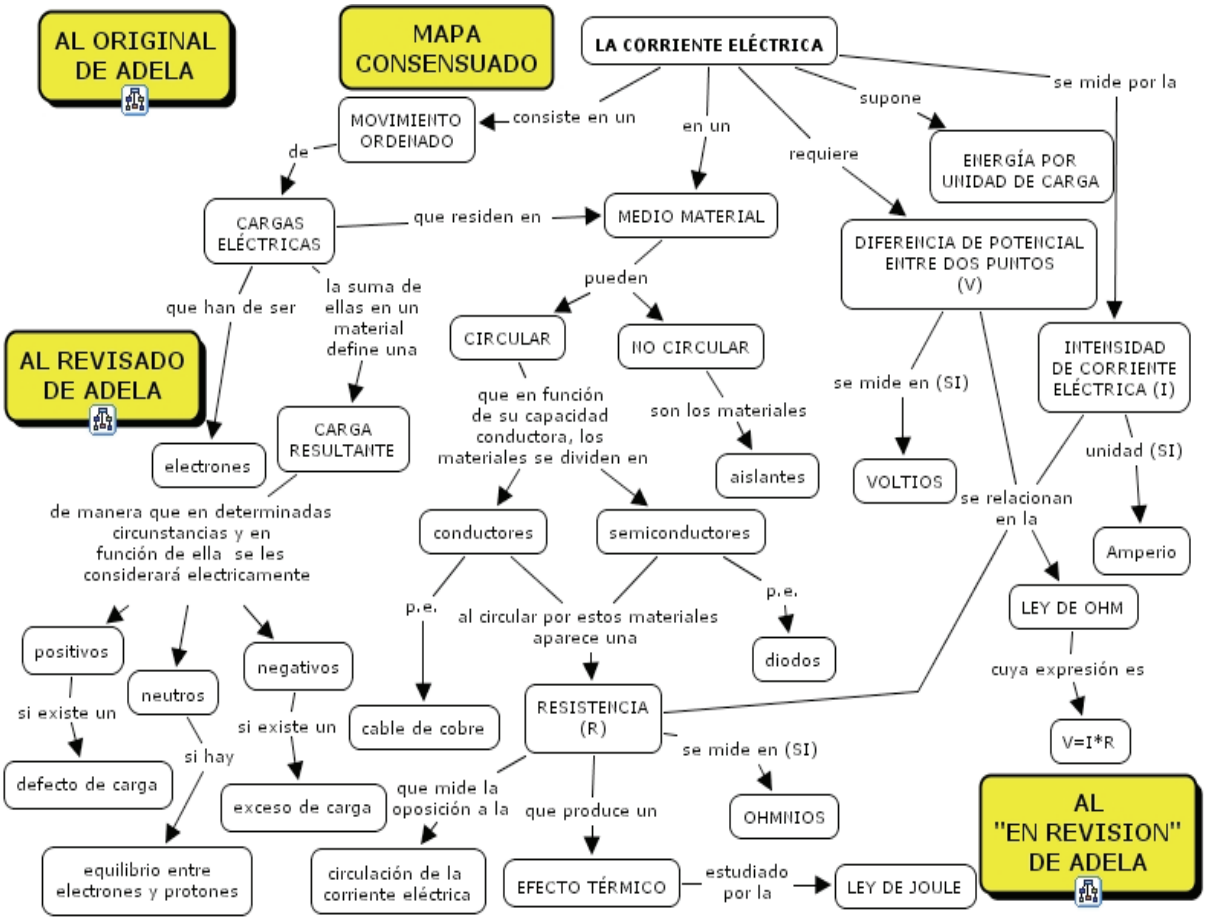


Cada uno de los alumnos participantes en esta experiencia modificó su mapa original aconsejado por sus compañeros de manera similar, y llegó a su mapa revisado por el autor que representa su manera particular de establecer las relaciones entre los conceptos considerados después de haberse visto obligado a realizar un reflexión concienzuda sobre el tema al tener que valorar las propuestas de modificaciones realizadas por el resto de los compañeros. La puesta en común estuvo llena de "anécdotas didácticas". Por lo que respecta al mapa de Adela hubo

una discusión muy encendida hasta concluir que, dado el nivel de los alumnos a los que supuestamente iba dirigido este mapa se estaba considerando únicamente la corriente eléctrica debida al desplazamiento de los electrones, excluyéndose por el momento todo lo relacionado con la electrolisis. Especialmente discutida fue la nota 5, concluyéndose que el concepto "conductor eléctrico" era ambiguo, ya que algunos alumnos le asignaban resistencia eléctrica 0 (o despreciable) y otros consideraban que cualquier material que dejara pasar una pequeña corriente eléctrica ya podía ser considerado conductor. En este último sentido estaba utilizado este concepto en el mapa de Adela y eso tenía consecuencias didácticamente indeseables cómo que lleva a afirmar (ver el mapa) que en los conductores se transforma energía eléctrica en energía térmica, lo que, aunque sea cierto, puede llevar a los alumnos a considerar que esa sea su función, cuando en realidad esta "pérdida" de energía es indeseable y siempre se pretende minimizar. Se concluyó que es preferible utilizar el concepto de "conductor eléctrico ideal" que no tiene resistencia eléctrica y, por lo tanto, no disipa energía. Se aconsejó a Adela que si alguna vez va a utilizar su mapa con alumnos lo vuelva a modificar de nuevo en el sentido comentado. También se aconsejó que no hable a sus futuros alumnos de cargas eléctricas positivas en movimiento refiriéndose a los protones, mejor no mencionarlo, pues los protones situados en el núcleo de los átomos no se pueden mover libremente ni los electrones situados en capas "profundas" de la corteza tampoco, solamente los electrones de la última capa de átomos unidos entre sí por enlaces metálicos pueden hacerlo (las cargas eléctricas positivas que se mueven por la acción de un campo eléctrico, los cationes, pueden ser de composiciones muy diferentes).

3.5 Mapa Consensuado

A continuación se incluye el mapa finalmente consensuado.



Para establecer un mapa conceptual sobre la corriente eléctrica lo más consensuado posible, se partió del mapa individual modificado por el autor que se consideró más completo y se le fueron añadiendo aquellas partes de los otros mapas ya modificados que se creyeron más relevantes. El proceso total fue complejo pues ninguna de las opciones consideradas gustaban por completo a todos los alumnos, a veces, se podía observar asomar un poquito de

"amor propio" en el afán por mantener la defensa de las propuestas realizadas por cada uno. Aunque este mapa haya sido consensuado por los alumnos, cada uno de ellos (incluido el profesor) modificaría algunas cosas, pero se respeta el consenso logrado entre ellos.

4 Evaluación de la Experiencia

A continuación se incluye un test sobre conceptos básicos de electricidad que fue pasado a los alumnos del Curso de Aptitud Pedagógica al año siguiente de la experiencia y que había sido pasado también en ediciones anteriores de dicho curso. Este curso del CAP, que venimos impartiendo desde hace más de 20 años, es obligatorio para aquellos alumnos (todos ellos licenciados en física, en química, ingenieros, arquitectos, etc.) que quieran presentarse a las oposiciones para optar a ser profesores de educación secundaria en España (en sus 4 últimas ediciones se han generado más de 700 Cmaps que pueden ser consultados en nuestro sitio Cmap de la universidad de Extremadura). Aunque el estudio detallado de los resultados obtenidos con este test y del porcentaje de veces que es escogido cada uno de los distractores de cada item no es objeto específico de esta comunicación, como valoración global, al comparar los resultados obtenidos en años anteriores por grupos de alumnos que no habían participado en la experiencia con los obtenidos por el grupo de alumnos participantes, se observa que éste último obtuvo unos resultados que superaban en un 17% el porcentaje de aciertos obtenido por el primero. Este resultado indica que los alumnos que entre las actividades llevadas a cabo un año antes en la asignatura de didáctica de la física relacionadas con la enseñanza/aprendizaje de la corriente eléctrica, utilizaron la metodología didáctica descrita en esta comunicación, habían aprendido 17% más que los que habían seguido un método convencional, o, más exactamente, que transcurrido un año desde la experiencia, los conocimientos retenidos por los primeros superaban en un 17% a los retenidos por los alumnos no participantes en la misma.

TEST SOBRE CONCEPTOS BÁSICOS DE ELECTRICIDAD

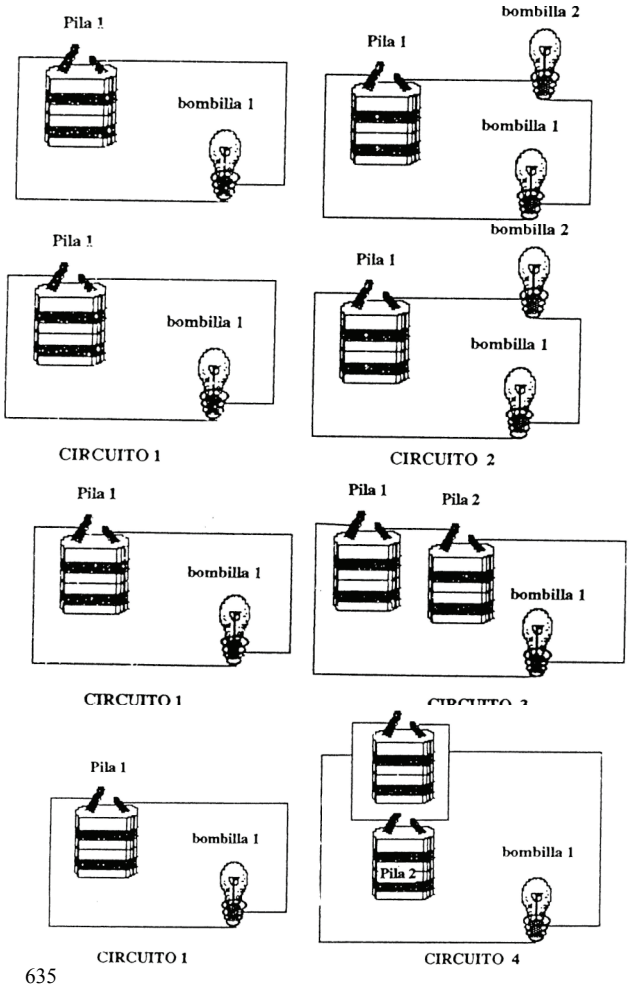
Nota preliminar: Se supone que todas las pilas, las bombillas y los interruptores son idénticos entre sí e ideales, así como también los cables de conexión.

1.- Observa los circuitos 1 y 2 de la figura. El brillo de la bombilla 1 será:
- a) Más en el circuito 1 que en el 2.
- b) Menos en el circuito 1 que en el 2.
- c) Igual en el circuito 1 que en el 2
- d) En el circuito 2 no lucirá.

2.- Observa el circuito 2 de la figura. El brillo de la bombilla 1 será:
- a) Mayor que el de la bombilla 2.
- b) Menor que el de la bombilla 2.
- c) Igual que el de la bombilla 2.
- d) La bombilla 1 no lucirá.

3.- Observa los circuitos 1 y 3 de la figura. El brillo de la bombilla 1 será:
- a) Mayor en el circuito 1 que en el 3.
- b) Igual en el circuito 1 que en el 3.
- c) Menor en el circuito 1 que en el 3.
- d) Nulo en el circuito 3.

4.- Observa los circuitos 1 y 4.de la figura. El brillo de la bombilla 1 será:
- a) Mayor en el circuito 1 que en el circuito 4.
- b) Igual en el circuito 1 que en el circuito 4.
- c) Menor en el circuito 1 que en el circuito 4.

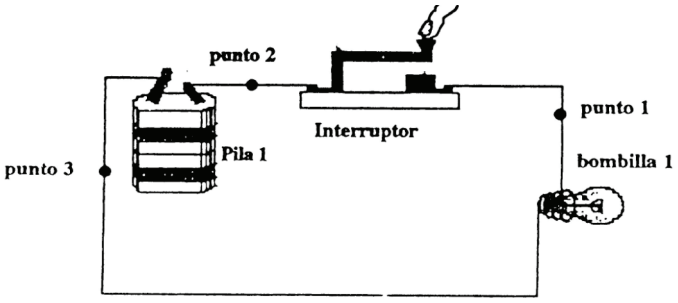


d) Nulo en el circuito 4.

5.- Observa el circuito 5 de la figura. La diferencia de potencial entre los puntos 1 y 2 será:
a) Mayor cuando el interruptor está pulsado.
b) Mayor cuando el interruptor está abierto.
c) Igual en ambos casos.
d) Nula cuando el interruptor está abierto.

6.- Observa el circuito 5 de la figura. La diferencia de potencial entre los puntos 1 y 3 será:
a) Mayor cuando el interruptor está pulsado.
b) Mayor cuando el interruptor está abierto.
c) Igual en ambos casos.
d) Nula cuando el interruptor está abierto.

7.- Observa el circuito 5 de la figura. La diferencia de potencial entre los puntos 2 y 3 será:
a) Mayor cuando el interruptor está pulsado.
b) Mayor cuando el interruptor está abierto.
c) Igual en ambos casos.
d) Nula cuando el interruptor está abierto.



CIRCUITO 5

RESUMEN GLOBALIZADO DEL RESULTADO DEL TEST

% de Aciertos	1	2	3	4	5	6	7	**MEDIA**
Grupo Control	52%	56%	61%	46%	54%	52%	68%	56%
Grupo Experimental	68%	66%	72%	72%	75%	73%	82%	75%
Mejora Conseguida	16%	10%	11%	26%	21%	21%	14%	**17%**

5 Agradecimientos

Al Ministerio de Educación y Ciencia, por el proyecto BFM2003-01465, correspondiente al Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica (I+D+i) y al programa FEDER de la Unión Europea.

6 Referencias

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., et al. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping* (Vol. I, pp. 125-133). Pamplona, España: Universidad Pública de Navarra.

Montanero, M., Pérez, A.L. y Suero, M.I. (1998). "Mapas conceptuales tridimensionales". XI Conferencia Nacional de Física e VIII Encontro Ibérico para o Ensino da Física. Libro de resúmenes. Porto (Portugal).

Pérez, A.L, Peña, J.J. y Mahedero, B. (1979). "Electronic device of didactic and electrometric interest for the study of RLC circuits". Am. J. Phys.: 47 (2), pág. 178-181 U.S.A.

Pèrez, A.L., Suero, M.I., Montanero, M. y Pardo, P.J. (2001) "Three-dimensional conceptual maps: an illustration for the logical structure of the content of optics". International Conference Physics Teacher Education Beyond 2000. Selected Contributions. R. Pinto & S Suriñach. ISBN 2-84299-312-8; pág 603-604. Editorial Elsevier Francia.

Pèrez, A.L., Suero, M.I., Montanero M. y Pardo, P.J. (2004). "Aplicaciones de la teoría de la elaboración de Reigeluth y Stein a la enseñanza de la Física. Una propuesta basada en la utilización del programa informático CmapTools En A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping*, Pamplona, España: Universidad Pública de Navarra.

Concept Maps: Theory, Methodology, Technology
Proc. of the Second Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, Eds.
San José, Costa Rica, 2006

VEE HEURISTICS, CONCEPT MAPPING AND LEARNING PATTERNS: MERGING METACOGNITIVE TOOLS AND LEARNING PROCESSES TO IMPROVE FACILITATION OF LEARNING WITH PRIMARY CHILDREN

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Abstract. This paper describes the merging of two learning tools, Vee Heuristics and Concept Mapping, with an advanced learning system, the Let Me Learn Process, to capture the learner uses of metacognitive skills during an extant learning event. Using student interviews and work product, this study traces the effect of a learner's mental operations on the learner's use of Vee Heuristics and Concept Mapping as the learner embeds and retrieves new and scaffolded knowledge. The data collected reveals the powerful effect which this combination of learning tools and learning processes yielded on student achievement. The significance of this study lies in the manner in which it lays open for the teacher the mind operations of the learner thereby equipping the teacher to better mentor and coach the growth and development of the learner rather than shape the learner through a one-size fits all learning environment as is too often the case in traditional schooling.

1 Introduction

Education is a journey and a very personal experience which may be enlightening for some but "merely an unengaging rite passage into adulthood" (Pinar ed., 1998:135) for others. Rousseau's writings emphasized the importance of making sense of the world in our own way "Childhood has ways of seeing, thinking and feeling peculiar to itself: nothing can be more foolish than to seek to substitute our ways for them" (Rousseau in Boyd's translation, 1956:38-39).

Nonetheless, the transmission model of education is still prevailing in many schools with children being lost to us. Even if students make it academically, Pinar argues that they "graduate, credentialized but crazed, erudite but fragmented shells of human possibility" (Pinar ed., 1995:519).

In view of this reality, one starts to ask "How can we help the children experience a journey of education which instills a desire to learn, reflect and act critically? As educators we need to reconceptualise pedagogy and modify the often conventional and restrictive practices in the classroom to a pedagogy where: "the child (is) aware of her own thought processes… and aware of how she goes about learning and thinking as she is about the subject matter she is studying" (Bruner, 1996:53).

But when and how does learning occur? While there are many who have contributed to our understanding of how learning occurs (James, 1904; Snow & Jackson, 1992; Sternberg, 1996), there are few who have developed a connected explanation of an individual's mental operations (cognition, conation and affectation) and resulting learning processes, i.e., how an individual takes in the world around him/her, makes sense of it, and responds to it in appropriate ways.

2 The Let Me Learn Process: An Advanced Learning System

The LML Process® is an advanced learning system whose theoretical basis is the Interactive Learning Model developed by Johnston, 1996. The Interactive Learning Model proposes that learning is a process occurring through the use of three mental processes: Cognition, Conation and Affectation and that these processes are the internal operations of our learning patterns namely: Sequential, Precise, Technical and Confluent and the degree to which each pattern is used varies from person to person. To measure the degree to which each learner uses each of the patterns, Johnston & Dainton (2005) developed the Learning Connections Inventory (LCI) which has withstood empirical and theoretical testing for more than ten years in different countries around the world. The LCI scores reveal whether one uses a learning pattern at a "Use First level, "Use as Needed" level or seek to avoid it altogether.

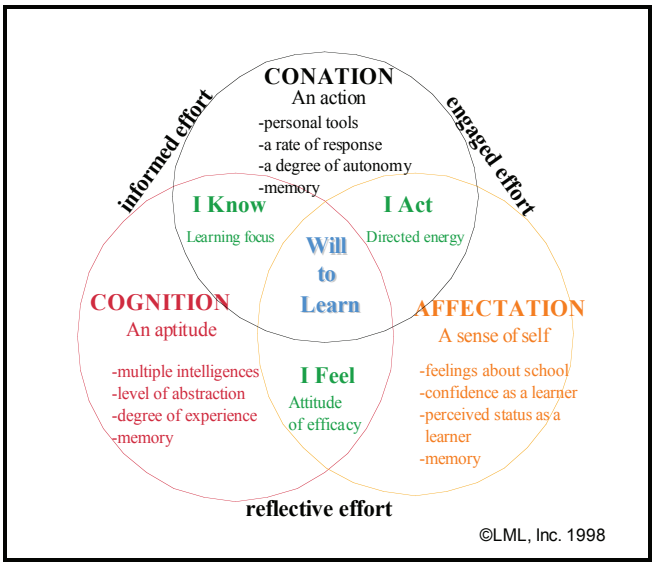


Figure 1: The Interactive Learning Model

The Sequential interaction is that aspect of our learning which needs to follow step-by step directions; organize and plan work carefully; and complete the assignment from beginning to end free from interruptions. The Precise interaction is that aspect of our learning which needs to process detailed information carefully and accurately; take detailed notes; ask questions; know exact answers; and write in a highly specific manner. The Technical Reasoning interaction is that aspect of our learning which requires practical application and relevance to any learning task. It is our non-verbal process which sees the mechanics of operations, the function of pieces; and needs to work "hands on", unencumbered by paper and pencil requirements. The Confluent interaction is that aspect of our learning which has us avoid conventional approaches; seek unique ways to completing any learning task; gives us permission to start before all directions are given; and permits us to take a risk, fail and start again (Johnston, 1996).

Let Me Learn Process does not categorize or place a learner into a single quadrant but instead emphasizes that every learner uses each of these interactive processes in concert and to varying degrees. These learning patterns, as presented in Fig. 2, serve as filters through which a stimulus moves from the brain's processing of it to the mind's action upon it. Such action includes translating the stimulus into symbolic representation (words, numbers, musical notes, etc), sorting and storing it within declarative and non-declarative memory, and retrieving it for later use. The Interactive Learning Model is based upon research conducted in cognitive science, brain science, and multiple intelligences (Allport, 1961; Bruer, 1993; Gardner, 1983; Johnston, 1996; Keefe & Ferrell, 1990; Snow & Jackson, 1992; Sternberg, 1996).

The Let Me Learn Process is based on the assumption that taking control of how one learns is powerful and positive (Flavell, 2000) and it provides a lexicon of learning terms and teaches metacognitive/reflective skills (Osterman & Kottkamp, 2004; Johnston, 1998). The LML Process helps learners take responsibility for making learning work for them by using carefully developed activities including a student designed, metacognitively-driven strategy card that guides the learner through various types of learning tasks. Unlike measures of personality, multiple intelligences, or learning styles which leave the learner informed but unequipped to use the information, the LML Process invites the learner to use these processes with intention. This is what makes the LML Process a truly advanced learning system.

The LML Process suggests in Fig. 2 that when stimuli enter the brain, the brain sends neuro impulses to the mind which translates the impulses into symbols that it can store, process and retrieve while at the same time it checks its prior experience and where it belongs within the declarative or non-declarative memory. This is where metacognition comes into play.

Bruer defines metacognition as "the ability to think about thinking, to be consciously aware of oneself as a problem solver, and to monitor and control one's mental processing" (Bruer, 1993:67). It is an intrapersonal communication where time is given to quietly think and reflect on what one is learning and on regulating how we go about learning (Vanhear & Borg, 2000). Metacognition challenges the transmissive view of learning and teaching held by certain teachers and the passive views of the role of the learners. While not dismissing the fact that metacognitive tools may be helpful, Georghiades (2000) reveals that primary school children who received metacognitive instruction performed better.

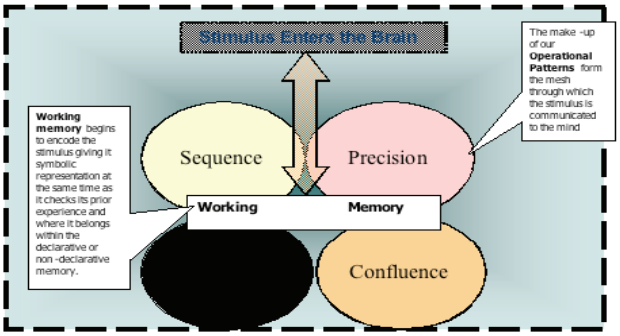


Figure 2: The LML Representation of the Architecture of the Brain and Mind. ©Let Me Learn, Inc. (Johnston, 2004)

3 Merging Two Tools with an Understanding of Our Learning Processes

This paper emanates from a Masters research carried out with six year old children, in which the following major research questions were constructed: How can I make new meaning relevant and meaningful to the learners? How can I know what's going on in their heads? Has meaningful learning really taken place?

The aim of this research was to focus on the process and technique of Vee Heuristics and Concept Mapping so as to improve meaningful learning. This process and development was captured through semi-structured interviews carried out with selected learners in order to observe details of the diverse children's knowledge, feelings and actions related to a specific focus question. Concept Maps and drawings related to a particular focus question were constructed from the data obtained **before** and **after** the project. Furthermore, all of this was put within a context of the different learners' learning patterns.

4 Methodology

The Vee Heuristic presented by Novak & Gowin (1984) was too complex to tackle with six to seven year old children. Therefore, I opted to make use of Ahoranta's adapted version of Åhlberg's improved Vee Heuristics which have withstood theoretical and empirical testing from 1993 to 2006 and have been applied to Environmental Education in Finland for several years (Åhlberg, 2002; Åhlberg in Cañas et al 2004; Åhlberg & Ahoranta, 2002; Åhlberg & Ahoranta in Cañas et al 2004) Nonetheless, considering that Ahoranta's work was with 11-12 year olds, the wordings in the eight steps presented by Ahoranta were adapted so as to facilitate the learners' understanding and application.

In Fig. 3 one can note that the first step in this process is to select a focus question. In order to capture the children's curiosity and empower them to become 'choosers' (Novak, 1998:51) while also encouraging them to actively take part in their own learning, one of their own questions was used as a focus question.

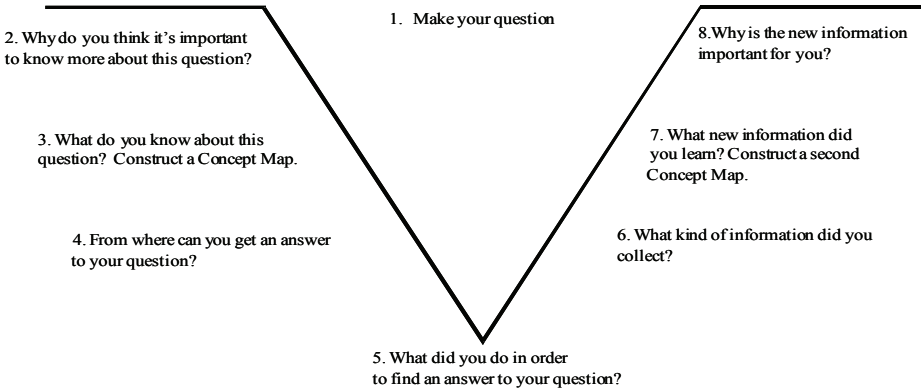


Figure 3: Ahoranta's Vee adapted by Vanhear

5 Data Analysis

From the data collected it was very clear that besides revealing that children come to class with prior knowledge and experiences, children process incoming information in different ways,. Vee Heuristics and Concept Maps facilitated an awareness of what children already know and how each of them actually processes new information. My prior knowledge of different learning patterns was value added to the process of Vee Heuristics and Concept Mapping. The path that this study has pursued is not to seek absolute truths but rather to shed light upon a pedagogical process which captures personal structures of knowledge and their development. Therefore, I preferred to make use of the same processes used throughout this research, i.e. Vee Heuristics and Concept Mapping for analyzing the data collected. Here are two examples from the collection of data.

5.1 Learner 1. Her LCI score was Sequence 17; Precision 18; Technical 23; Confluence 27 (7-17= Avoid; 18-24=Use as Needed; 25-35=Use First)

This learner uses Confluence first, avoids the use of Sequence and uses her Technical Reasoning and her Precision only when needed. This means that detailed instructions and directions do not make sense to this learner; she prefers to learn in a creative and entertaining way, she likes to do things in her own way and differently each time, and she doesn't feel the need to follow any rules.

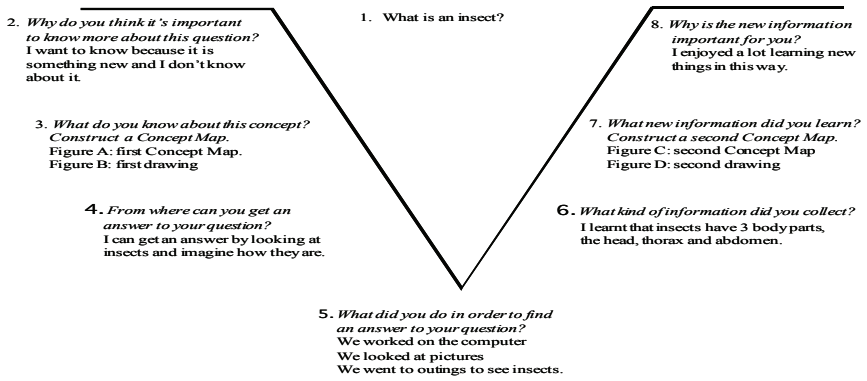


Figure 4: Learner 1 Vee Heuristic.

The left hand side of the Vee Heuristic presented in Figure 4 reveals that for this learner the primary reason for wanting to know more about the focus question was because it presented something completely new to her (confluence). From reply No.4 one can observe the different way how this learner planned to learn about this question. She didn't refer to learning from books or detailed information but she referred to imagination (confluence) and observation instead. This is substantiated in reply No. 5 where although in this learning programme specific lessons and books were available, this learner didn't mention these at all as the primary sources for her learning, but on the other hand she mentioned the computer, pictures and outings. The right hand side reveals the new knowledge constructed and how she integrated it within her pre existing cognitive structure. This learner expressed that she enjoyed learning new things in this way thus suggesting an increase in her motivation.

By analyzing the two Concept Maps presented in Figures A and C, one can easily conclude that the number of concepts and propositions have increased drastically. More concepts and propositions indicate that learning has taken place. The learner also detected her misconceptions and missing information in the first Concept Map and made the necessary changes and additions in the second Concept Map. Being a learner who scores high in confluence and low in precise and sequence, she usually looks unmotivated to learn in the classroom setting. Consequently, this second Concept is amazingly impressive. She was able to demonstrate a high ability for learning new concepts and she also mentioned details, which would have probably passed unnoticed through the traditional way of teaching. I am referring to details such as the word "arthropods" and its meaning, what insects eat, the concept of pollination etc…. This Concept Map evidences that this learner really enjoyed learning and was motivated to learn in this way.

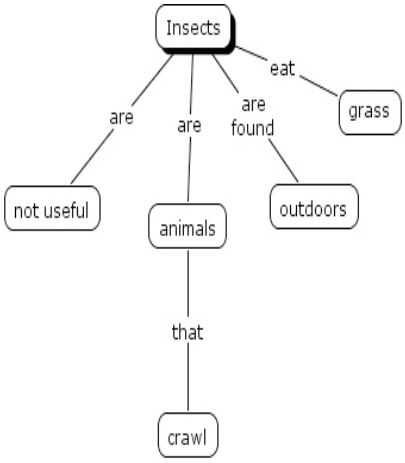


Figure A: First Concept Map

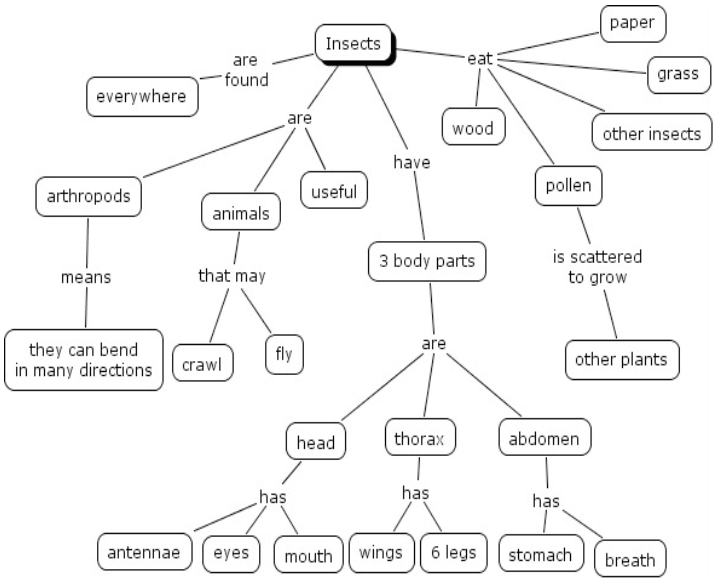


Figure C: Second Concept Map



Figure B: First drawing before the learning program



Figure D: Second Drawing after the learning program

From the difference in the two drawings one can note some of the new concepts that the learner developed. The first drawing is lacking detail while it represents exactly what the learner's cognitive structure of knowledge was about insects and which is similar to her first Concept Map before the learning project. It also reveals the misconception, present in this learner's cognitive structure, related to the number of legs. On the other hand, the second drawing reveals the development of new concepts and the correction of the previous misconception about the legs. One has to note that in the second drawing the three body parts and the six legs are very distinct. On the head one can see the eyes and the mouth and the antennae which are labelled. These were all new concepts which were also present in the second Concept Map.

5.2 Learner 2. Her LCI score was Sequence 16; Precision 22; Technical 27; Confluence 20.

Here we have a 'dynamic' learner (Johnston, 2005) who makes use of Technical Reasoning at a Use First level. She uses her Confluent and Precise processing as needed while she avoids Sequence processing. From this learning pattern, one can deduce that this learner doesn't like to write in detail, she makes use of very few words to express herself, she prefers to work by herself and needs to see the purpose for what she's doing. Furthermore, she tends not to read directions since she finds following directions quite confusing if not even frustrating.

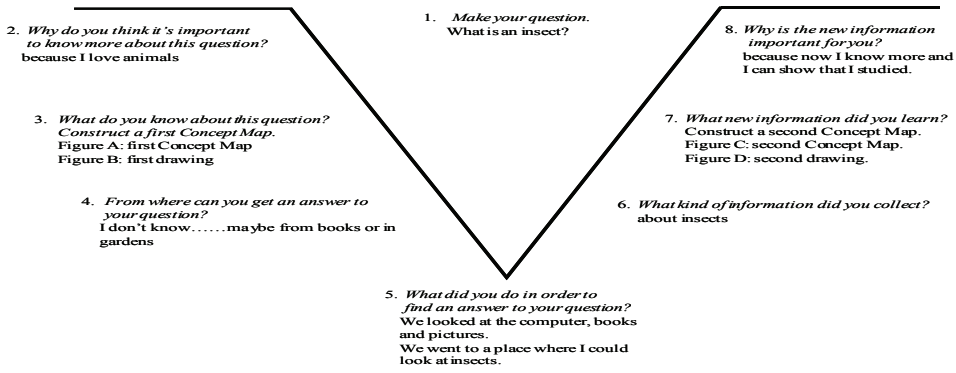


Figure 5: Learner 2 Vee Heuristic

In this Vee Heuristic it is very interesting to note the difference in the answers on each side. On the left hand side, which reveals responses given before the learning programme took place, one can note this girl's uncertainty in going through this programme. Reply No.1 is quite vague whereas reply No. 4 shows that she isn't sure from where she can get an answer. This clearly conveys the message how lost this child felt before going through this learning programme.

On the other hand, the right hand side reveals a difference in this girl's confidence. Her response to question 5 was quite immediate, detailed and sure, thus showing that her sense of security and motivation increased along the learning programme. Furthermore, it is quite appealing to note the response to question 8: *"because now I know more and because I can show that I studied"*. One of this learner's main concerns is not what she learnt but how she's going to show it. In fact, this learner's learning patterns reveal that she finds it difficult to express what she knows especially through tests since she doesn't like writing in detail besides following too many sequential directions. It is no wonder that she is concerned about this, she is aware that she knows but she finds it difficult to express it. From reply No. 8 one can conclude that she was satisfied to be able to show what she learned. Concept Mapping offered her another way of expressing what she knows. When asked what she thinks about her second Concept Map, she replied: *"it shows that I have studied"* something a learner high in the use of technical reasoning is often accused of not doing because they do not see it as important to tell others what they know!

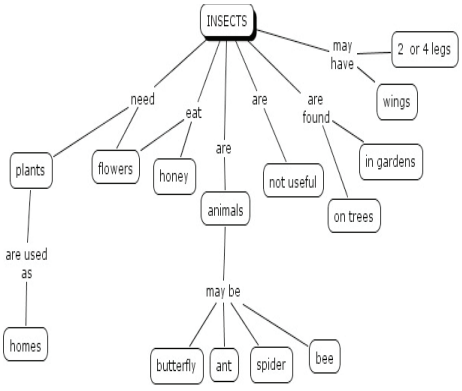


Figure A: First Concept Map

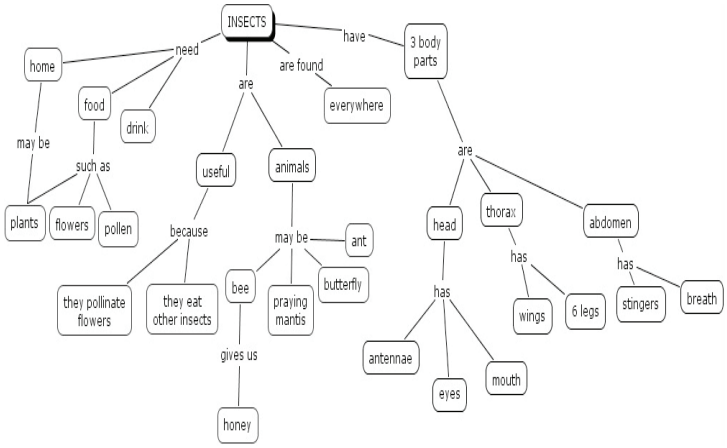


Figure C: Second Concept Map

When one compares the two Concept Maps, presented in Figures A and C it is very easy to deduce that the number of concepts and propositions has increased thus indicating that learning has taken place. From the interview with this girl I noted how quickly she was changing and adding on to her map. This revealed her confidence and eagerness to show what she has learnt besides showing how easy it was for her to externalize her cognitive structures in this way. She was enjoying watching her map expand. We can note that she was able to correct all the misconceptions present in the first Concept Map such as *"insects have 2 or 4 legs"*, *"insects are not useful"* or *"insects eat honey"*. She was also able to make changes to the concept of honey.

Referring again to this learner's learning patterns, we are aware that she finds difficulty in expressing what she knows and that she avoids sequence. This is maybe why the misconception *"insects eat honey"* occurred in the first Concept Map. Nonetheless, she was able to adjust this misconception and relate to it appropriately in the second Concept Map. In fact, we can see that this concept appears again in the second Concept Map only this time in the proposition *"bee gives us honey"*.



Figure B

This learner's motivation through this kind of process of learning is also very explicit in her drawings. Figure B shows the drawing before the learning project and it is clear to see her motivation and lack of confidence at this stage. Figure D reveals the radical change that took place within this learner's motivation to learn. In fact, the second drawing, gives precise details.

The changes present in the Vee, in the Concept Maps and the drawings clearly demonstrate that learning in this way increased the learners' motivation thus affecting positively on their learning. Moreover, Concept Maps seemed to offer a practical way to exhibit what they learned, though I have to remark that they needed prompting while constructing their second Concept Map.



Figure D

6 Discussion

Novak (1998) reveals that the shape of a Vee was chosen above other shapes because by using this format, one can clearly recognize and differentiate that both thinking (concepts and theories) and doing (methodology) are implicated in the process of constructing knowledge. The right hand side of the Vee, reports the action part of knowledge construction taking place. One can, in fact, visually see what the learner is doing to develop his/her own knowledge. In addition, the learner can reflect and observe the development of the new knowledge taking place as opposed to his/her prior knowledge on the left hand side of the Vee. In this way, prior knowledge was developed; misconceptions were altered while new knowledge was constructed. Thus, the transmission model of education is hereby challenged since the learner is learning on his own, the teacher is only facilitating this process by providing the necessary tools. It is argued that rote learning does not impart meaningful learning and one way of taxing this approach is through the use of metacognitive learning. Research in this study and elsewhere prove that Vee Heuristics promote metacognitive skills. Similarly, Novak argues that *"giving learners the correct information does not displace their faulty conceptions! It takes a lot of negotiation of meanings, a lot of shared experience to help learners reconstruct their internal concept Maps to be congruent with the expert's knowledge"* (Novak, 1998:118). This is where the knowledge about Let Me Learn becomes most fruitful, since with an awareness of the diverse children's learning patterns one is in a much better position to negotiate meanings and experiences in a way which make sense to the learners. The cognitive structures represented in this way made it relatively easy to follow the development of new knowledge and the specific changes in the learner's knowledge structure since Concept Maps give a specific picture of what the child has in her/his head (Kinchin, Hay & Adams 2000, Cañas et al 2004).

Moreover, this whole process makes the teacher stop and reflect on his/her own practice. In order to bring about transformation one must be ready to transform oneself first and foremost and the starting point should be to reflect critically for "If we want pupils to learn meaningfully and reflectively, then their teachers ought to first learn how to learn meaningfully and reflectively" (Åhlberg in Cañas et al 2004:39).

7 Conclusion

My prior knowledge of the Let Me Learn Process and my newly acquired awareness of Vee Heuristics and Concept Mapping led me to study the effects of merging these tools. Through the Let Me Learn Process, I could better understand how the student learns while Vee Heuristics and Concept Mapping visually represented the learners' metacognition throughout their acquirement of new and related knowledge.

When teachers understand what students think about concepts or events under study and are aware of how they learn, they are better able to formulate a partnership in learning based on the learner's needs.

8 References

Åhlberg, M. (2002) Advanced Concept Mapping and Vee Heuristics as quality learning tools to promote Environmental Education and Education for Sustainability. *Paper presented in ATEE RDC 17 Annual Conference* Aug. 24-28, 2002. Warsaw University, Poland.

Åhlberg, M. & Ahoranta, V. (2002). Two improved educational theory based tools to monitor and promote quality of geographical education and learning. *International Research in Geographical and Environmental Education* 11 (2), 119 - 137.

Allport, G. (1961). *Pattern and growth in personality*. New York: Holt, Rinehart & Winston.

Boyd, W. (1956) *Emile for Today: The Emile of Jean Jacques Rousseau*. London: Heinemann.

Bruer, J. T. (1993). *Schools for Thought: A Science of Learning in the Classroom*. Massachusetts: The MIT Press Cambridge.

Bruner, J. (1996). *The Culture of Education*. USA: Harvard University Press.

Cañas, A. J. Novak, J.D., González, F.M. (eds) (2004). *Concept Maps: Theory, Methodology, Technology. Proceedings of the First International Conference on Concept Mapping. Vol. I & II.* Navarra, Spain: Dirección de Publicaciones de la Universidad Pública de Navarra.

Flavell, J., Green, F., & Flavell, E. (2000). Development of Children's Awareness of Their Own Thoughts. *Journal of Cognition and Development*. 1,1,97-113.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Georghiades, P. (2000). Beyond Conceptual Change Learning in Science Education focusing on Transfer, Durability and Metacognition. *Educational Research* 42 (2), 119-139.

James, W. (1904). *Talks to teachers on psychology: And to students on some of life's ideals*. New York: Norton.

Johnston, C.A. (1996) *Unlocking the Will to Learn.* California: Corwin Press.

Johnston, C.A. (1998). *Let Me Learn*. Thousand Oaks, CA: Corwin Press.

Johnston, C. A.(2004). *Learning to Use My Potential: A Catalogue of Resources*. Turnersville, NJ: Learning Connections Resources.

Johnston, C., & Dainton, G. (2005). *The learning Connections Inventory* (Manual). Thousand Oaks, CA: Corwin.

Keefe, J. & Ferrell, B. (1990). Developing a defensible style paradigm. *Educational Leadership*, 48(2), 57-61

Kinchin, I.M., Hay, D.B., Adams, A. (2000) How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research* 42(1) 43-57.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept Maps as Facilitative Tools in Schools and Corporations*. Mahweh, NJ: Lawrence Erlbaum Associates.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

Osterman, K. & Kottkamp, R.(2004). *Reflective practice for educators: Professional development to improve student learning*. Second Edition. Thousand Oaks, CA: Corwin

Pinar, W.F., Reynolds, W.M., Slattery, P. & Taubman, P.M. (1995). *Understanding Curriculum*. N.Y.:Peter Lang

Pinar, W.F. (ed) (1998). *Curriculum: Toward New Identities*. New York: Garland Publishing Inc.

Snow, R., & Jackson, D. (1992). *Assessment of conative constructs for educational research and evaluation: A catalogue*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Sternberg, R. (1996). Myths, countermyths, and truths about intelligence. *Educational Researcher*, 25(2), 11–16.

Vanhear, J. & Borg, A. (2000). *The Interactive Learning Model: Profiling Learners' Learning Patterns*. Unpublished B.Ed. Thesis: University of Malta.

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WWMAPS, A COMMUNITY ON EDUCATION THROUGH COLLABORATIVE CONCEPT MAPPING

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Abstract. *WWMAPS* supports and coordinates educational practices and training initiatives focusing on construction of Concept Maps and shared Knowledge Models between students worldwide, through the universal language of Concept Mapping. During the nine months from the foundation, we have looked for technological solutions and partners, we have arranged web services, we have started up and monitored several collaboration teams in primary and secondary schools. Now we can evaluate these first results and study better practices for next and current collaborations. This paper is submitted to the Concept Mapping community to open a discussion about theoretical assumptions, goals, methodologies, difficulties and strengths to gain educational benefits from this kind of distance collaboration.

1 Introduction

Concept Mapping is now a tool of pedagogic mediation that facilitates meaningful learning. *Knowledge Models* (Cañas et al., 2003) arranged as structures of *Concept Maps* (Novak, 1984) linked among them outstandingly allow to organize complex fields of knowledge in a dynamic way. If both processes are implemented properly, they can have significant educational implications along the constructivist line. C-maps are more than graphic tool for the representation of already assimilated knowledge; they act as pedagogic, iconic and symbolic mediators, and visual-linguistic *organizers* which are able to shape paths, scaffolding individual or group cognitive processes. Moreover, the new technologies add value to Concept Mapping, in terms of motivation, flexibility and use, of opportunity of sharing and collaboration. Sustained on these pedagogical resources, we thought of undertaking an initiative that could stimulate the educational community for the use of c-maps.

Those who join the *WWMAPS* (World Wide Maps) community are encouraged to use concept mapping since their students will build and map knowledge domains in collaboration with distant students who speak a different language. In order to learn the basic language of concept mapping, few criteria are sufficient to be repeated in practice in a systematic and strict way to obtain immediate results. Motivated members in a community of practices "absorb" the criteria of building c-maps that are used within the community. We have inherited a shared model for concept mapping by a similar process of discussion as members of Italian community map.dschola (Guastavigna et al, 2004; http://it.wikipedia.org/wiki/Mappe_concettuali). These are the reasons why we have chosen this strategy, which, at the same time, gives a training environment and the certainty of achieving significant educational goals. The "learning by doing" method does not exclude the most traditional training methods. Advanced training initiatives like the one that are being implemented in Panama within the framework of project *Conéctate* (IHMC, 2005), show that it is possible to achieve a significant convergence between the two strategies, thus applying constructionist criteria in training and making the relative community play an active role.

2 Theory

C-Maps are made up of a network of basic propositions (subject– verb – object forming a meaningful semantic unit) whose structure does not change during translation. The hierarchical arrangement of propositions helps the reader make the difference between main and secondary concepts. Compared to the text where the same idea is often repeated and is often hidden by synonyms and metaphors, C-Maps are built with the least number of concepts and words, thus reducing complexity. Therefore, even if the reader is not an expert in the topic or has a poor knowledge of the language, s/he will understand the meaning and the context easier thanks to all these factors. For the same reasons the translation of a concept map is easier than the translation of a text having the same meaning and context. Concept Maps oblige to make clear and to elicit even those underlying conventional meanings which are shared within a local community such as a classroom. The students of a different class can read all significant ideas that are shown in the concept map. Moreover, thanks to technology (Cañas et al., 2004), a C-Map can be built by students from different countries as a shared working environment where resources – images, audio and video texts, web

pages, etc – are introduced to discuss about life experiences, culture or other contents. Therefore, thanks to C-Maps it is possible to set up significant communication and interaction with the least number of words.

2.1 Multilingual C-Maps

BiK-map (Bahr & Dansereau, 2004) gave us the hint to use maps, as the communication "interface" between two different languages. In Concept Maps relationships must be complete and detailed, thanks to explicit and exclusive phrases-links of every pair of concepts given. On the other hand, K-Maps have only nine kinds of labels that indicate general relationships (Characteristic of, Example, Leads to, etc.) Bilingual Knowledge Maps in well known contexts were successfully used to facilitate the learning of a foreign language. We think that complete bilingual C-Maps - with explicit link-phrases - are needed to communicate a complex knowledge, dealing with unfamiliar contexts, between pupils speaking different languages.

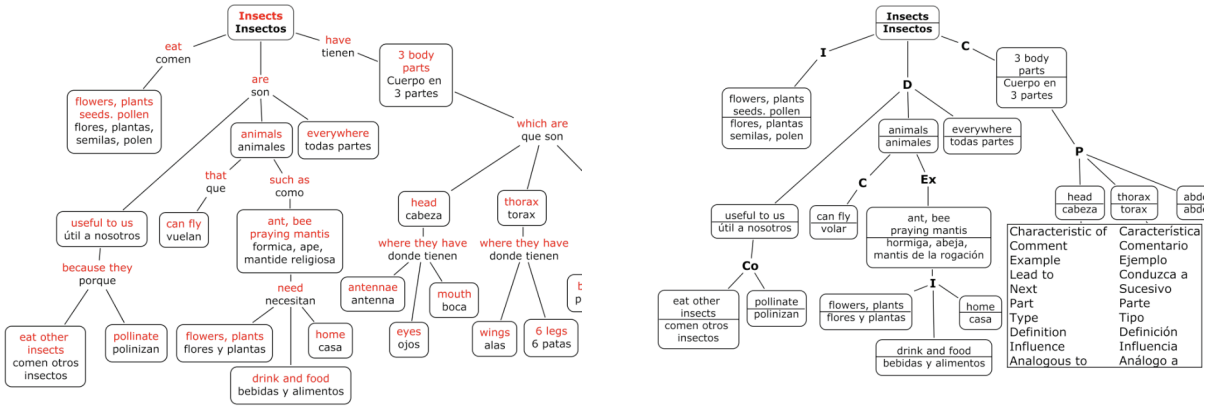


Figure 1. Comparison between a Bilingual Concept Map (left, excerpt translated from Michaela, six years old) and an equivalent Bilingual Knowledge Map (right). Linking phrases are hard to infer from coded links in unfamiliar contexts, particularly for Influence.

2.2 Collaboration through Concept Mapping

Project Quorum (Cañas, 1995, 2001) in the early 1990's in Latin America can be considered the first large scale experiment to take advantage of telecommunication links between schools and to demonstrate that meaningful learning can be encouraged through the use of concept maps. Coffey and Cañas (2000) affirm that in online distance education, interactive concept maps might be used as tools to produce effective learning. In fact, concept maps stimulate knowledge integration processes by making knowledge explicit, and by requiring the learner to pay attention to the relationships between concepts (Dutra & Fagundes, 2004). *CmapTools* is unique as a tool to establish collaborations and to share concept maps and knowledge models. Ortegano-Layne & Gunawardena (2004) envisaged that the CmapTools software could be used as a tool to foster online collaborative learning in distance education and realized the importance to provide training on how to collaborate using concept maps in an online environment. CmapTools and Concept Maps were chosen also as an instrument for resolution of conflicts (Beirute, 2004). It is admitted indeed that writing concept maps implies deconstruction and reconstruction of knowledge (as in conflicts) in a new hierarchical and impersonal structure of meanings capable to give a deeper understanding and an insight to that knowledge domain. So we can imagine practices where collaborative concept mapping, triggering negotiation of meanings, could be beneficial to learning (Basque, 2004).

3 Goals

WWMAPS has the following goals:

1. To disseminate Concept Mapping as an educational practice.
2. To share methodologies among teachers from different countries.
3. To increase the mutual knowledge of cultural realities in the world.

4. To build shared knowledge in disciplinary or professional (for teachers) domains.
5. To facilitate the learning of a second and third language.
6. To create the largest number of international collaboration teams.
7. To create a community on collaboration practices through Concept Mapping.

4 Methodology

Concept maps are the most "transparent" and efficient way to show and support, at a metacognitive level, the changes occurring when a student integrates new knowledge with the pre-existent one. In case of collaboration, knowledge will be shared within a work group having the same expectations as for the individual use of C-Maps. Moreover, the need for collaboration fosters the use of maps, thus strengthening the metacognitive tools the student owns.

4.1 How is a collaboration team set up

The teachers who know and are interested in the *WWMAPS* initiative connect to the "Join" web page http://www.2wmaps.com/public/participate.htm where they find the instructions to fill in the form with the data of students concerning the town, the age, their preferred topics of collaboration, the language etc. within a map called "MeToo". The successful entry of data in the appropriate box means that the potential member has downloaded and installed the necessary software (CmapTools v4), has learnt its basic functions and has a reliable connection to end the operation. Thereby s/he can join the community as a new member. Through the coordination of *WWMAPS*, the teacher interested in a collaboration comes into contact with a suitable pre-existing team or s/he contacts other teachers until partners with compatible characteristics are found.

Thereby every new team is set up according to a general topic although significant interaction among partners is necessary to change such a general idea in a clear-cut project: from highlighting specific topics up to focal questions that will start up the collaborative construction of C-Maps among students. Each team develops a "project map" in collaboration with a member of *WWMAPS* staff. Project Maps are similar to concept maps – sometime they are bilingual – although their syntactic structure is more flexible. Several solutions were adopted to keep trace of the path: nodes of different colours were used to make a difference among the authors of contributions, every time the versions changed they were saved with a legend to show the main changes. Nevertheless, team members used annotations. In some cases Project Maps are used as Home–Maps for knowledge models. Secondary-school students can also actively participate in the design and realization of the Home-Map. The team work is supported by an appropriate forum.

4.2 Collaboration among Students

In the design phase the schools and the groups of students to be involved get to know each other. At the same time students and teachers get familiar with the *WWMAPS* project and its tools (ex. tutorial on the use of CmapTools and on how good concept maps are built). Many students practice the foreign language when writing a personal description. This task can also be facilitated by using the "octopus self-intro" map (a map with eight tentacles, describing the pupil, attached to a root node with his/her portrait – name) which is easier to be customized and read than a text. The respective teachers will now coordinate students to start the works that will be worked out on parallel resources or carried out alternating work sessions on the same resource. The different forms of cooperation mainly rely on three parameters: *complexity, mutuality and autonomy*.

Complexity: evaluation of the frequency, degree of diversification of communication forms, of resources and representations of knowledge required to guarantee method and rhythm to the process of knowledge construction. Attainable complexity mainly relies on the age of the students involved and can be gradually increased throughout the process of team working experience.

Mutuality: It shows the degree of interaction and interdependence that students who collaborate must have. In order that distance collaboration makes sense, students should have a common task, share resources, examine and criticize partners claims, make common decisions, support and wait for each other as a condition to go ahead, celebrate together the outcomes. This is very different from working independently from each other!

Autonomy: independence of the activity from the coordination of tutors and teachers. Collaborating teams are based on the mutual work of students. Teachers contributes should vanish and their role should be limited to supervision and coordination, that comprises stimulation, encouragement, rising key questions, fixing technological problems, mirroring a positive sense of effectiveness and challenge in the progressing work. Furthermore, autonomy can be progressively enhanced by progressing experience and supported by a good preparatory training on C-maps.

Examples of collaboration methods	*possible required parameters* (1 = minimum, 2 = medium, 3 = high)		
	Complexity	*Mutuality*	*Autonomy*
1. Each partner develops its own map on a common topic and examine the work of the other. The exchange rises from the comparison, using annotations or discussion threads.	1	1	3
2. Both partners work on the same C-Map, editing it in turn, following rules to inform the other about the introduction and the modification of contents, but without sharing tasks. Explanations shall also require an exchange.	2	3	2
3. Both partners work on the same complex map or on the same knowledge model, suggesting and agreeing upon sub-topics to be developed. Links between sub-topics situated in different maps are also possible.	3	3	2

Table 1: Different types of collaboration and efficiency parameters required (just an indication)

Each class can be divided into more groups that can also be formed by each student who are "twinned" with other distant partners. All students or groups can work in parallel on the same topic or otherwise each unit in the class can deal with one or more particular aspects. Therefore, it is necessary to define the cooperating unit within the cooperation team, as a group of subjects coming from different countries who work on one single c-map.

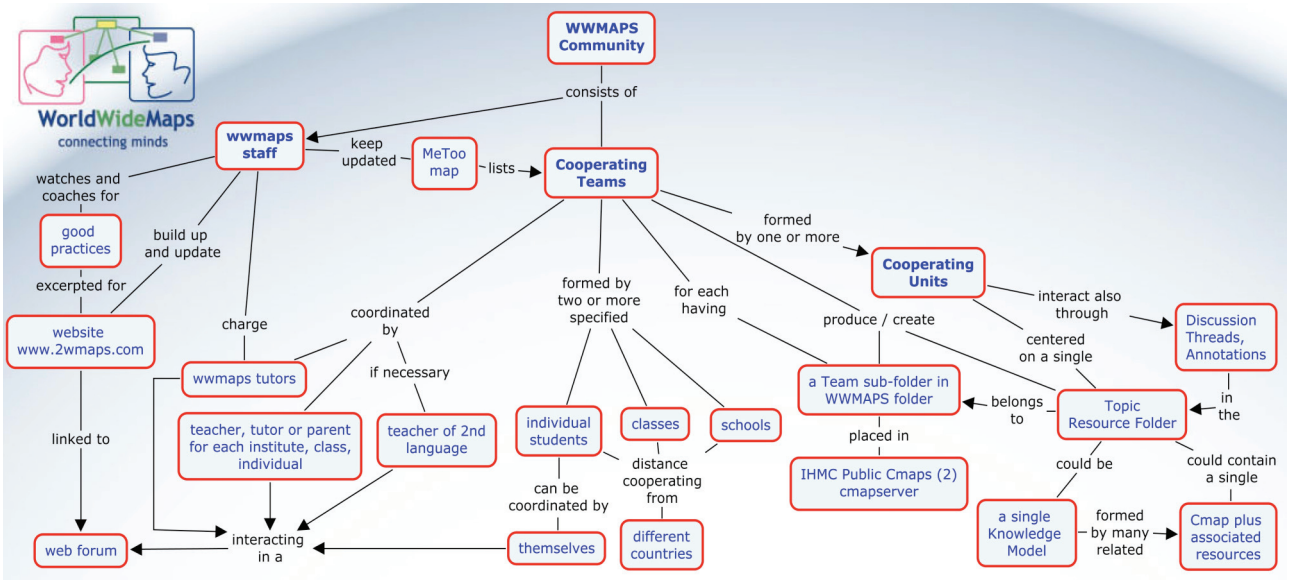


Figure 2. Structure and relationships in WWMAPS community

The choice of the most appropriate organizational solution and any change in progress are the topics of the coordination of each team, whereas the project staff deals with monitoring.

4.3 Which tools the technology offers to allow the collaboration

The CmapTools technology offers the possibility of sharing concept maps and other network resources. In this way it is possible to collaborate among distant partners and develop concept maps or more complex structures as knowledge models that modify and become bigger with new "branches". The simplest tool of discussion to make decisions on the work in progress that is also the most widespread one among started teams is the *Annotation*. For more complex discussions, *Discussion Threads* can be used by putting them in one of the main concepts in a map.

On the other hand we got round some of the limitations of *asynchronous collaboration* in CmapTools: as for the lacking of automatic chronology, where we save successive old copies using the number of the version (i.e. mapname_old01, mapname_old02 etc.), thus keeping the original name (e.g. mapname) for the most updated version. Notification of changes takes place in the respective forum of collaboration teams (where automatic e-mail alert is implemented). Another collaboration tool that can also be used in asynchronous method is the *Knowledge Soup* (Cañas et al,. 2001). The sharing of such a repository of claims which are independent from the context, rather than of a C-Map, enables the team partners to be more flexible and autonomous. They can choose the shared claims from the Soup, and enter them as unchanged or modified propositions in the map. However, the current technology is not fit for soups from bilingual maps; therefore the Knowledge Soup was tested only for maps in a common language or within the same partner. As for the collaboration method n.1 (Tab. 1) the use of the Knowledge Soup would increase the interdependence and mutuality level among partners. Asynchronous collaboration best suits working rhythms of partners who generally add their contributions weekly and in different times. However, the CmapTools technology also permits *synchronous collaboration*. Accordingly, distance training micro-activities could be carried out with the same efficiency as classroom lessons which are very useful to harmonize the skills of team members at the beginning of the collaboration.

5 The first results

The teams worked autonomously and developed the collaboration process by keeping contact through e-mail and autonomous forums. The first phase consisted in realising auto-presentation maps of the schools, the classes, and the students. Then, once defined, the general topics were divided into project maps and assigned to groups of students coming from different partner classes. Afterwards, the students began to build the maps and to connect resources in different cooperative forms.

After only a few months of activity, different teams started to collaborate (interact) with students and to produce a large number of maps and knowledge models which are opened to further development, like open building sites. It is difficult for even one of these processes to find enough space in this article, therefore, we will limit ourselves to a synthesis chart (current status of the teams is accessible from www.2wmaps.com/Eng.htm, link "keyhole").

Team	**Partners**	**Topics; *Development stage***
AntAna	Italy, Spain; P.S.	Knowledge of the countries and of the traditions; *Compared maps*
CoBeCast	Italy, Costa Rica; P.S.	Dying or at risk species of animals, Compared and *Shared C-Maps*
ItEspa	Italy, Spain; P.S.	Citizenship and Human Rights; *Shared C-Maps*
LaBeMal	Italy, Malta; P.S.	Citizenship and Human Rights; *Compared and Shared C-Maps*
MalToBe	Italy, Malta, Spain; P.S.	Science: materials and their properties, recycling, concept of interaction; *Compared and shared C-Maps; shared Knowledge Model on physical-chemical interaction*
PanamBe	Italy, Panama;P.S.	Knowledge of the traditions*; first shared c-map on Christmas*
ReLaCo	Italy, Costa Rica; P.S.	Intercultural exchange from ancient civilizations, alimentation, body health; *first C-Maps to compare.*
Physics	Italy, Romania; S.S.	Forces, Measures; *Compared C-Maps; K-8 constructed c-maps that was reviewed by K-10 students*
Physics 2	Italy, Romania; S.S.	Light theories; *Training starting from skeleton C-Map, knowledge model on photoelectric effect*
StoryMath	Romania, Mauritius; S.S:	applications of geometry in different fields (art, biology, architecture, etc.) and historical development of mathematics; *Eight C-Maps on History of math by students from Romania; searching for a new partner.*

ZaSeMa	Italy, Mauritius, Spain; S.S.	Water management; *Collaborative knowledge modelling*
ZaSs	Italy, Spain; S.S.	European Union*; Collaborative knowledge modelling*
Synapsis	All partners expert in educational psychology	Psychological aspects of learning and teaching; *Collaboratively developed expert C-Maps becoming a knowledge model.*

Table 2: description of *WWMAPS* teams from primary school (P.S.), secondary school (S.S.) and expert adults

Below an example of concept map developed collaboratively in an asynchronous way by the team LaBeMal.

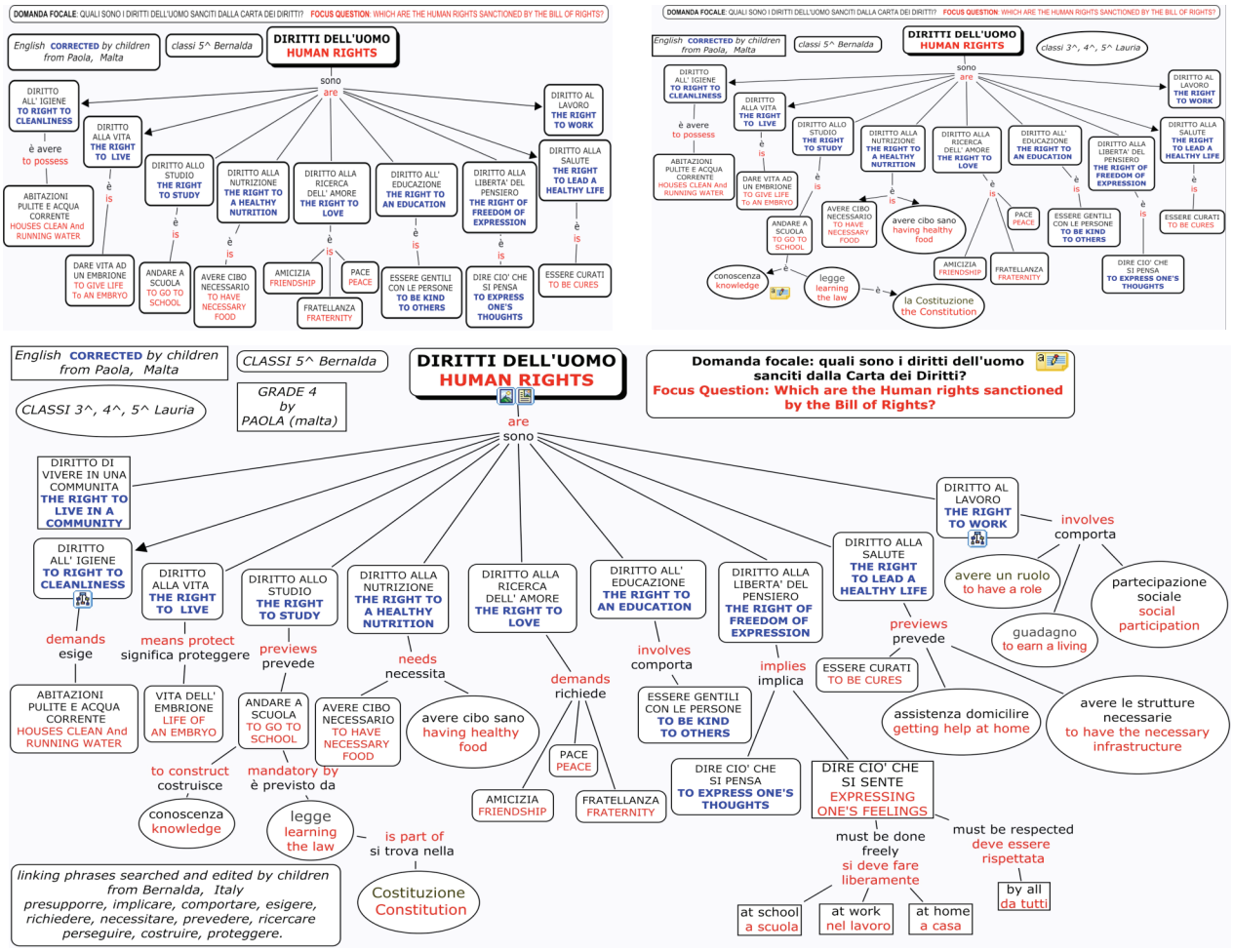


Figure 3. Two intermediate phases and the current version of a collaborative C-Map from team LaBeMal. Translation by children. Italian children searched for accurate linking words from synonyms dictionary and fitted them.

6 Evaluations and future program

The evaluation of the cases, based on monthly reports from the staff coordinators of each team, and of this whole experience, is still in progress. A first evaluation concerns the duration of the collaborations which depends on the following factors:

1. school calendars of the partners do not coincide. The students must wait for the end the each other's vacations to resume their collaboration. This is the case for the collaborations between Italy and Panama (PANAMBE), and between Costa Rica and Italy (COBECAST e RELACO).
2. experience of concept mapping by the team's partners. Teams constituted by experts in concept mapping spend less time to begin and realize the work, while less skilled partners need a gradual approach to get used to the software and to the CM methodology.

Other ”building sites” become less productive when the initial spur fades because of the “exhaustion” of the fixed arguments or because of the preference of a partner for another team. Such situations require both good timing for the collaboration between students and its development in a short period of time. In any case the collaboration between teachers should carry on without any fixed deadline with the alternation of different groups of students. In fact, the purpose of *WWMAPS* is to consider both the cooperation between students and the sharing of methodologies between teachers. The latter will be fruitful only in a long period of time.

For the future we will try to combine partners with a similar experience in concept mapping. The less experienced once will have a tutor who will not be involved with his/her students in the same team. As for the more qualified partners who will experience higher forms of co-operations (e.g. knowledge soup, synchronous collaboration), we rely on the Instituto Educativo Moderno in Costa Rica (www.iemonline.org) and on the schools supporting the Proyecto Conéctate al Conocimiento (IHMC, 2005), that has a strategic importance in Panama and that is already included among our collaborators.

As we anticipated, the multilingual concept maps have been quite easily translated in two and three languages by the students who even expected their partners to correct the mistakes, and have been used as effective interfaces to communicate complex knowledge (such as about the photoelectric effect, human rights, functioning of European Community, waste recycling, etc.) or to compare geographic mountain ranges, the extinction of animal species, religious and popular traditions and political – social organization of different partner regions - cultures. In the case of the team Italy-Spain, “ZaSs”, the translation of the knowledge model on the European Union has been made a lot easier by sharing the multilingual portal http://europa.eu.int, suggesting us a general strategy of sharing multilingual websites as common team bases of research.

The successful short training in *Physics 2* team demonstrated the need of another resolution for beginner-level teams, consisting in exercises to learn how to build good C-Maps, before dealing with the decided themes.

An advanced *constructionist model* for the collaborations should be attained, in which the role of a coordinator teacher, besides being a support in the collaborating group, must aim at controlling the processes and helping students to became autonomous in their achievements. The students have their own ideas on many things, for example on political elections. Therefore, they should have the possibility:

1. to elicit their prior knowledge in building basic concept maps that we can call “cognitive matrices”;
2. to commit themselves into critical confrontation. To become more aware of the differences and of the richness of the experiences, to start processes of comparison, negotiation of the significations, differentiation, extension and generalization. All spurred from the wish to see what the students of their age from other countries do and how they live the experiences about the subject and how they represent them;
3. to start a meta-cognitive phase through the reconstruction and synthesis of knowledge together with new revisions, with selections, with hierarchical organisation of concepts, and common decisions on how to structure the work. The children must be aware that this third phase must be *always* realised, in which knowledge must be systematized, and that the work cannot be done by others for them.

It is obvious that this really constructionist model of education is incompatible with an objective-based pedagogy because the realistic target is something that becomes clear on the way, depending on the effective possibilities of the class and of the instructional context. This is how we intend to respect the teacher’s professional autonomy, by entrusting her/him with the responsibility of the educational relationship an not by using other ruinous deterrents.

7 Conclusions about the main goal

The wealth of our community derives from the variety of collaborative solutions experienced in the single teams. The consolidation and the maturation of the *WWMAPS* community demand but an ulterior effort so that discussions, debates and comparisons do not remain limited to the dynamics within the single teams if we want to add a further level of true collective discussion. One of the greater obstacles for the attainment of this goal is due to the linguistic difficulties of many members, although they all are good teachers and trustworthy as collaborators. For this purpose we will try to use shared multilingual concept maps to focus the common debate on the methodologies, on the

constructionist approach to distance collaboration through concept maps, and on the training for reliable concept mapping. Such strategy should increase the levels of interdependence between members, allow an effective comparison and review of the practices, foresee which direction the project should take and, after all, assign a role of reference to *WWMAPS* in the scene of the practices on collaborative education.

8 Acknowledgements

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9 References

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Cañas, A J., Ford, K. M., Hill, G., Brennan, J, Carff, R., Suri, N., Coffey, J. (1995). *Quorum: A Collaborative Network for Latin American Schools,* presented at the 12th International Conference on Technology and Education – ICTE '95, Orlando, FL.

Coffey, J., Cañas, A. (2000, November 6-9). *A learning environment organizer for asynchronous distance learning systems*. Paper presented at the Twelfth IASTED International Conference Parallel and Distributed Computing and Systems, Las Vegas, Nevada.

Cañas, A. J., Ford, K. M., Novak, J.D., Hayes, P., Reichherzer, T. R., & Suri, N. (2001). *Using Concept Maps with Technology to Enhance Collaborative Learning in Latin America* The Science Teacher, 68, (pp. 49-51). Also from: www.ihmc.us/users/acanas/Publications/QuorumSoupST/SoupsST.htm.

Cañas, A. J., Hill G., Lott, J. (2003). *Support for Constructing Knowledge Models in CmapTools* Technical report IHMC CmapTools 93-02. From: http://cmap.ihmc.us/Publications/WhitePapers.php

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M., & Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In: A. J. Cañas, J. D. Novak & F. M. González (Eds.), Concept Maps: In: *Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra*.

Bahr, G. S., Dansereau, D. F. (2004). Bilingual Knowledge (BiK-) Maps: Study Strategy Effects. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory; Methodology, Technology, Proc. of the 1st International Conference on Concept Mapping. Pamplona, Spain: Univ. Pública de Navarra*.

Basque, J., Pudelko, B. (2004). The Effect of Collaborative Knowledge Modelling at a Distance on Performance and on Learning. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology, Proc. of the 1st Int. Conf. on Concept Mapping. Pamplona, Spain: Univ. Pública de Navarra*.

Beirute, L., Mayorga, L. F. (2004). *Los Mapas Conceptuales Herramientas ponderosa en la Resolución Alternativa de Conflictos*. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory; Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra*.

Dutra, I. & Fagundes, L., (2004). Un Efoque Constructivista para Uso de Mapas Conceptuales en Educación a Distancia de Profesores. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory; Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping. Pamplona, Spain: Universidad Pública de Navarra.*

M., Guastavigna, Ambel, M, Carletti, A., Casulli, L., Gineprini, M., Lombardi, A., Mattioda, P., Pantò, E., Tifi, A., Trinchero, R., Vayola, P., Zucchini, D, (2004). A Community of Practices on Concept Mapping. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory; Methodology, Technology, Proc. of the 1st International Conference on Concept Mapping. Pamplona, Spain: Univ. Pública de Navarra*.

Ortegano-Layne, L.& Gunawardena, C. N. (2004). Synthesizing Social Construction of Knowledge in Online Conferences using Concept Maps. In: A. J. Cañas & J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory Methodology, Technology, Proc. of the 1st Int. Conference on Concept Mapping. Pamplona, Spain: Univ. Pública de Navarra*.

Florida Institute for Human and Machine Congition (2005). *IHMC Researchers Enhancing Education in Panama*, IHMC Newsletter Volume 3, Issue 2 (pp. 7,8). From: www.ihmc.us/newsletters/IHMCnewslettervol3iss2.pdf. See also: www.conectate.gob.pa.