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Concept Maps: Theory, Methodology, Technology

Proceedings of the First International Conference on Concept Mapping

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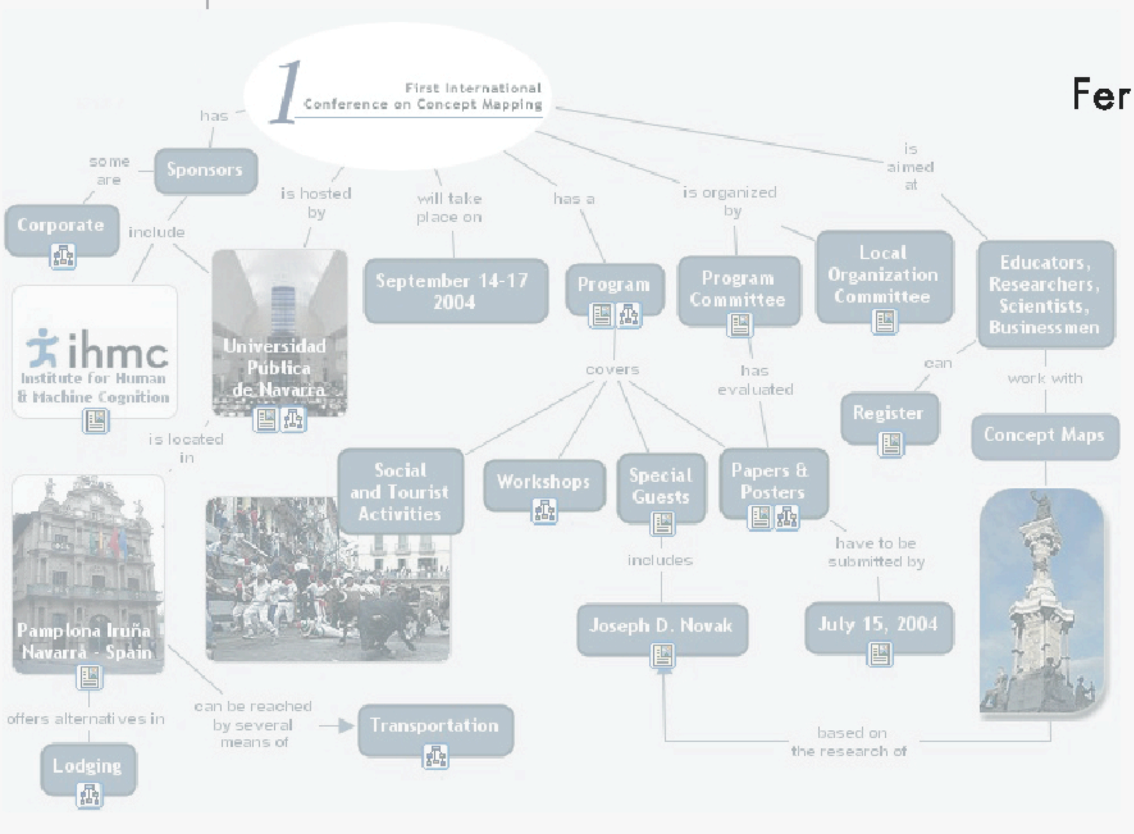

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CONCEPT MAPS & VEE DIAGRAMS AS TOOLS FOR LEARNING NEW MATHEMATICS TOPICS

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Abstract. This paper presents the data for 6 students who participated in a study that investigated the use of the metacogntive tools of concept maps and vee diagrams in learning and solving problems for selected mathematics topics. The six students used the tools to learn about new mathematics topics. Initially, students struggled to understand their new topics and the tools. However, with independent research and progressively mapping their findings on concept maps and vee diagrams, and with critiques and feedback from others, students eventually developed enhanced and deeper understandings of their chosen topics.

1 Introduction

The study reported here is part of a series of concept map and vee diagram studies (mapping studies) conducted as part of an undergraduate research course at the National University of Samoa (NUS). The mapping studies conducted with different cohorts over a number of semesters were driven by the need to explore how students' understanding of mathematics could be improved beyond the algorithmic and procedural knowledge that they are equipped with after years of schooling. Students also have difficulties communicating and arguing mathematically (Richards, 1991; Schoenfeld, 1996), transferring and applying what they know in solving novel problems (Afamasaga-Fuata'i, 2003a, 2002). Thus, it was important for mathematics education that research be conducted to explore students' perceptions of guiding principles for problems they are able to solve. For example, having students identify the relevant conceptual bases for a given problem and its solution would reveal the existing state of students' mathematical understanding and perceptions of what constitutes relevant mathematical knowledge. The case study of Nat (one of the cohort of 7-students) is presented in the paper entitled "*An undergraduate student's understanding of differential equations through concept maps and vee diagrams*" included in these proceedings, is one of a student who chose a familiar topic to concept map and vee diagram. His initial concept map and initial vee diagrams of problems were basically procedural. However, over the semester and with critical comments during presentations his maps/diagrams evolved to ones that were more conceptual and theoretical. Through the use of maps/diagrams, he gained a more comprehensive, integrated, and differentiated conceptual understanding of ordinary differential equations.

The six students (rest of 7-student cohort) whose data is reported here selected mathematics topics they had not encountered before in their recent advanced mathematics courses. Hence the challenge was for them to learn about and develop an understanding for the new topic through the construction of concept maps and vee diagrams (maps/diagrams). They were also expected to present their work publicly to their peers in a group setting and to the researcher in a one-on-one consultative session. During the presentations, they were expected to demonstrate and communicate their understanding of the new topic clearly and succinctly so that the critics (peers and researcher) could make sense of it. Part of the newly established socio-cultural practices in the classroom setting (socio-mathematical norms) were the expectations that they undertake independent research on their topic, be prepared to justify their constructions, address concerns raised and negotiate meanings during critiques.

The theoretical framework of the study is the Ausubel-Novak theory of meaningful learning, which describes meaningful learning as the process in which the student chooses to relate new information to existing knowledge (Ausubel, Novak & Hanesian, 1978; Novak, 2002, 1998, 1985). This process may be facilitated through the construction of concept maps and vee diagrams. Having students identify main concepts and organize them into a concept hierarchy of interconnecting nodes with propositional links can indicate the existing state of students' cognitive structures or patterns of meanings. The establishment of socio-mathematical norms of presenting individual work and critiquing peers' work is based on the principles of social constructivist and socio-linguistic perspectives which view the process of learning as being influenced and modulated by the nature of interactions and linguistic discourse undertaken in a social setting (Ball, 1993; Schoenfeld, 1996; Ernest, 1999; Richards, 1991; Knuth & Peressini, 2001).

2 Methodology & Data Analysis

The study was conducted as an exploratory teaching experiment (Steffe & D'Ambrosio, 1996) using the metacognitive tools of concept maps and vee diagrams (Novak, 1985, 2002) with students presenting their work for group and one-on-one critiques. After completing practice sessions in constructing maps/diagrams and presenting work in a social setting for critique, students selected their new topics for the application of the meta-cognitive tools. Students engaged in the cyclic process of presenting→ revising→ critiquing→ presenting for at least three iterations over the semester. The data from the six students consisted of progressive concept maps (4 versions) and vee diagrams of four problems (at least 2 versions each). The six students (Student 1 to 6) chose the topics Laplace's transform, trigonometric approximations, least squares polynomial approximations, multivariable functions and their derivatives, partial differential equations and numerical methods of solving first order differential equations. Each student's case is presented first, beginning with the concept map data and then followed by a general discussion of their vee diagram data, before discussion of general themes.

2.1 Concept Map Analysis

The qualitative approach adopted in the analysis of the data is a modification of the Novak scheme of scoring concept maps (Novak & Gowin, 1984). This paper uses only counts of occurrences of each criterion. Collectively, the criteria assess students' concept maps in terms of the *structural complexity of the network* of concepts, *nature of the contents* (entries) of concept boxes (nodes) and *valid propositions.* The structural criteria indicate the extent of integrative crosslinks between concepts and progressive differentiation between levels whilst the contents criteria indicate the nature of students' perceptions of mathematical knowledge. Valid propositions are those formed when 2 valid nodes are interconnected with appropriate linking words correctly describing the nature of the inter-relationship. The structural criteria are also assessed in terms of average hierarchical levels per sub-branch, multiple branching nodes, sub-branches and main branches. Particular examples are those used to illustrate concepts. Inappropriate entries at nodes are those that describe a procedural step, redundant concepts and linking-word-type. Redundant entries indicate students' tendency to learn information as isolated from each other instead of identifying potential integrative crosslinks with the first occurrence of the concept or consider a re-organization of the concept hierarchy. Linking-word-type indicates students' difficulties to distinguish between a "mathematical concept" and descriptive phrases. A proposition is invalid if linking words were missing, incorrect or end nodes had inappropriate entries. Data for the six students' progressive concept maps (first and final maps) are shown in Tables 1 and 2 below.

Reference	**Art**	**Art**	**Ada**	**Ada**	**Lou**	**Lou**	**Asi**	**Asi**	**Afa**	**Afa**	**Les**	**Les**
Student	**1**		**2**		**3**		**4**		**5**		**6**	
Map	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**
Concepts	14	24	8	19	13	43	12	51	13	43	36	84
Examples	0	0	2	0	0	0	1	0	2	2	2	4
Definitional	0	2	2	6	0	0	3	0	0	0	0	0
Inappropriate	3	0	2	2	0	0	1	0	0	1	2	17
Total	17	26	14	27	13	43	17	51	15	46	40	105
Concepts	82%	92%	57%	70%	100%	100%	71%	100%	87%	93%	90%	80%
Examples	0%	0%	14%	0%	0%	0%	6%	0%	13%	4%	5%	4%
Definitional	0%	8%	14%	22%	0%	0%	18%	0%	0%	0%	0%	0%
Inappropriate	18%	0%	14%	7%	0%	0%	6%	0%	0%	2%	5%	16%
Valid Prop	6	18	6	17	12	41	6	42	14	47	40	87
Invalid Prop	11	5	8	14	0	1	10	17	2	2	5	28
% Valid	35%	78%	43%	55%	100%	98%	38%	71%	88%	96%	89%	76%
Integrative Crosslinks	1	1	0	0	4	6	0	4	0	4	7	18

Table 1: Contents, Propositions and Crosslinks Criteria

Student 1's topic was Laplace's transform (LT). From his research, Art selected a few concepts for his first map to provide a definition for LT, and to illustrate how they are used in solving initial value problems. His first concept map had 17 nodes of which 14 were valid with 3 inappropriate ones due to procedural, redundant and link-word-type entries. Only 35% of the propositions were valid with only one integrative crosslink, see Table 1. The high proportion of invalid propositions was due to missing or inappropriate linking words. At the first group critique, critical comments focussed on the need to reconsider the hierarchical order of concepts, missing relevant concepts and inappropriate concept labels. Comments from subsequent critiques over the semester pinpointed areas of confusion, which guided Art to sections of his map that needed re-organization and re-structuring to enhance its intended meaning. By the end of semester, Art's final concept map showed an increase in valid nodes (from 14 to 24) with significantly more valid propositions (from 35% to 78%), more sub-branches (from 6 to 10), higher average hierarchical levels per sub-branch (from 4 to 6), an additional main branch (from 3 to 4) and an increased number of multiple branching nodes (from 4 to 8), see Table 2. Overall, Art's final concept map had become more integrated and complex as his understanding expanded and became more enriched as a result of critiques, revisions and individual research. For example, he wrote: "*with concept maps, its uses that I have experienced from the semester is that they broaden my understanding of my chosen topic... (constructing concept maps) allows the writer to easily understand his own topic through substantial and more comprehensive links and to simply make changes from comments in class presentations.*"

Reference	**Art**	**Art**	**Ada**	**Ada**	**Lou**	**Lou**	**Asi**	**Asi**	**Afa**	**Afa**	**Les**	**Les**
Student	**1**		**2**		**3**		**4**		**5**		**6**	
Map	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**	**1**	**4**
Sub-Branches	6	10	4	8	3	15	6	20	4	19	14	32
Hierarchical Levels	4	6	4	7	8	8	4	7	4	9	10	15
Main Branches	3	4	2	3	1	6	3	4	3	5	4	5
Multiple Branching Nodes at:												
Level 1	2	2				2	2	2	2			
Level 2	2	3,2	2			3		3,2				
Level 3	2,2	2,2		2		2,2	2,3	2,6		4	2	2
Level 4		2	2	5	2	2		3,2,3	2	2,4,2		
Level 5			2			2,2,2,3	2	3		2	2	2
Level 6		2			2	2,2				2	2,2	2
Level 7		2				2,3		2,2,2	2	2	2,2	2
Level 8						2		3		2	3,2	
Level 9										2		2,3
Level 10				2						2		2,2
Level 11										2	2	2
Level 12										2,2	2	3,2,3,2
Level 13										2		2
Level 14										2		2,2
Total # Multiple Branching Nodes	4	8	3	3	2	14	4	13	3	15	10	16

Table 2: Structural Criteria

Student 2's topic was Trigonometric Approximations. Ada found his topic hard, but after reading a few textbooks, he chose to approach his topic using his background knowledge of Taylor's polynomial. For example, he chose to demonstrate the concept of approximations of values of a compound trigonometric function by successively approaching the point. Thus, the first map was mainly procedural but with time and critiques, his final map evolved into a more conceptual one with the demonstration of method of application relegated to a vee diagram. For example, Ada wrote in his report: "*I was forced to look for key concepts involved in Taylor's polynomial and how they are interrelated to other branches of mathematics. I sought how the terms in the series functioned and what relationship they had to practical applications like speed, acceleration and distance, forming the ability to use this tool in other situations. … Overall, it was a difficult but helpful experience in which I have a deeper understanding of Taylor's polynomial but as yet many unanswered questions.*" Ada's final concept map had relatively more valid concepts (from 8 to 19). Unfortunately, 6 nodes had definitional phrases, which require further analysis to form more succinct conceptual entries. There was also an increase in valid propositions (from 6 to 17) but the inordinately high invalid propositions (from 8 to 14) is due to missing linking words, and inappropriate-end-nodes (definitional phrases).

Student 3's topic was least squares polynomial approximation (LSPA). Lou's first concept map consisted of one main branch with only two multiple branching nodes, and four integrative crosslinks, see Table 2 for data and the left map in Figure 1. From the first group critique, she realized that her map did not provide sufficient concepts to explain the main ideas relevant to her topic particularly the concept of *errors* in spite of having included the concept of *squared differences*. Hence, with more readings, and research, she added in concepts of *errors*, *five-point-least-square-polynomial*, *smoothing formula*, *data smoothing* and *n^{th} degree* to name a few, for her first revisions. However, as she wrote in her report: "*Despite the clustered and plentiful information given in my map, the main concept of errors is lost. This is because there was less emphasis on understanding the topic. Rather, a collection of various concepts seemed more important at the time. Hence, an improved map would require meaningful concepts, mathematical formula, neater presentation, and simple examples. I learnt here that the basic idea behind the topic is that there is an error and everything falls around the minimising of this error.*" With more critiques, further research for additional concepts and subsequent revisions, Lou realized that the concepts of *Least-square polynomial P(x)*, *Function F(x)* and *Error = Y(x) – P(x)* have to be positioned appropriately and the case for *continuous data* required further clarification. By her third revision, Lou noted that her revised map "*showed a clear hierarchy of linking concepts … hence it was easier to follow what the map is trying to tell us. However, there is still work to be done on clarification, organization and available information.*" She also learnt that "*organization plays a huge role in making the map comprehensive.*" With more critiques and revisions, Lou's final concept turned out to be a "*a much more effective one in terms of understanding the concepts related to the topic (LSPA). So, the idea of errors was clear, its application and determination was also specified, and the table for clarification of Newton's formula, was also a great improvement.* " In summing up her experiences in the study, she wrote: "*I have now seen an evolvement from a very basic map to a more complicated one. The surprising fact discovered is that the basic map (i.e. first map) was more confusing than the resulting one (i.e. final map).*" This is quite a revealing statement about the value of her final map as a more meaningful, comprehensive and informative piece of work. Part of Lou's final map is shown in the right map in Figure 1 for comparison to her first attempt.

Student 4's topic was multivariable functions and their derivatives. Asi's first concept map had 12 valid nodes with 4 invalid nodes due to a definitional phrase and inappropriate entries. The invalid propositions (10 out of 16) were due to missing linking words or inappropriate nodes. In spite of Asi's efforts, the group found her first concept map presentation confusing due to vague and inappropriate linking words. Asi then revised and reorganized her concept hierarchy to make the map more meaningful. Subsequent one-on-one and group critiques over the semester eventually resulted in a final map which was more differentiated with increased multiple branching nodes (from 4 to 13), and sub-branches (from 6 to 20) with a higher average hierarchical levels per sub-branch (from 4 to 7). In response to critical comments, Asi reorganized the concept hierarchy, revised linking words to make them more descriptive of interconnections, created more sub-branches, and provided meaningful integrative crosslinks to improve the clarity and organization of information. Overall, the final map had significantly more valid nodes (from 12 to 51) and valid propositions (from 6 to 42). Asi wrote in her final report: "*To me, using concept maps has given me a chance to learn more of my research topic.*"

Student 5's topic was numerical methods of solving first order differential equations. Afa's first concept map had 15 valid nodes of which 2 were examples, 3 multiple branching nodes, and 4 sub-branches with average hierarchical levels of 4 per sub-branch. Through critiques and subsequent revisions, his final map evolved into one that was more differentiated and enriching with substantial increases in sub-branches (from 4 to 19), average hierarchical levels per sub-branch (from 4 to 9), main branches (from 3 to 5), integrative crosslinks (from 0 to 4), and multiple branching nodes (from 3 to 15). Overall, valid propositions increased from 14 to 47.

Student 6's topic was partial differential equations (pdes). Les' first concept map had 38 valid nodes with only 2 invalid ones due to redundant entries. The map differentiated between first and second order pdes with further differentiation at lower levels into homogenous and non-homogeneous types, and had 40 valid propositions with only 5 invalid ones due to incorrect/vague linking words and inappropriate end nodes. With further critiques and subsequent revisions, Les' final map eventually evolved into one that was substantially more complex with increases in sub-branches (from 14 to 32), average hierarchical levels per sub-branch (from 10 to 15), multiple branching nodes (from 10 to 16) and integrative crosslinks (from 7 to 18). Valid propositions had also increased from 40 to 87. However, the higher number of invalid propositions (from 5 to 28) is due to an increased number of inappropriate nodes due to procedural, redundant and linking-word-type entries and missing linking words. Les created additional sub-branches in the final concept map to provide conceptual bases for his vee diagram problems. He wrote in his final report: "*I myself understand fully the path from one concept to another and how a conclusion can be obtained because I created the concept maps.*" He continued on to state that "*From my experience in laying out my concept map I have learnt that differentiating first order and its special cases and second order and its special cases avoids confusion. It helps me to classify each pde I come across so that I could see the big picture.* "

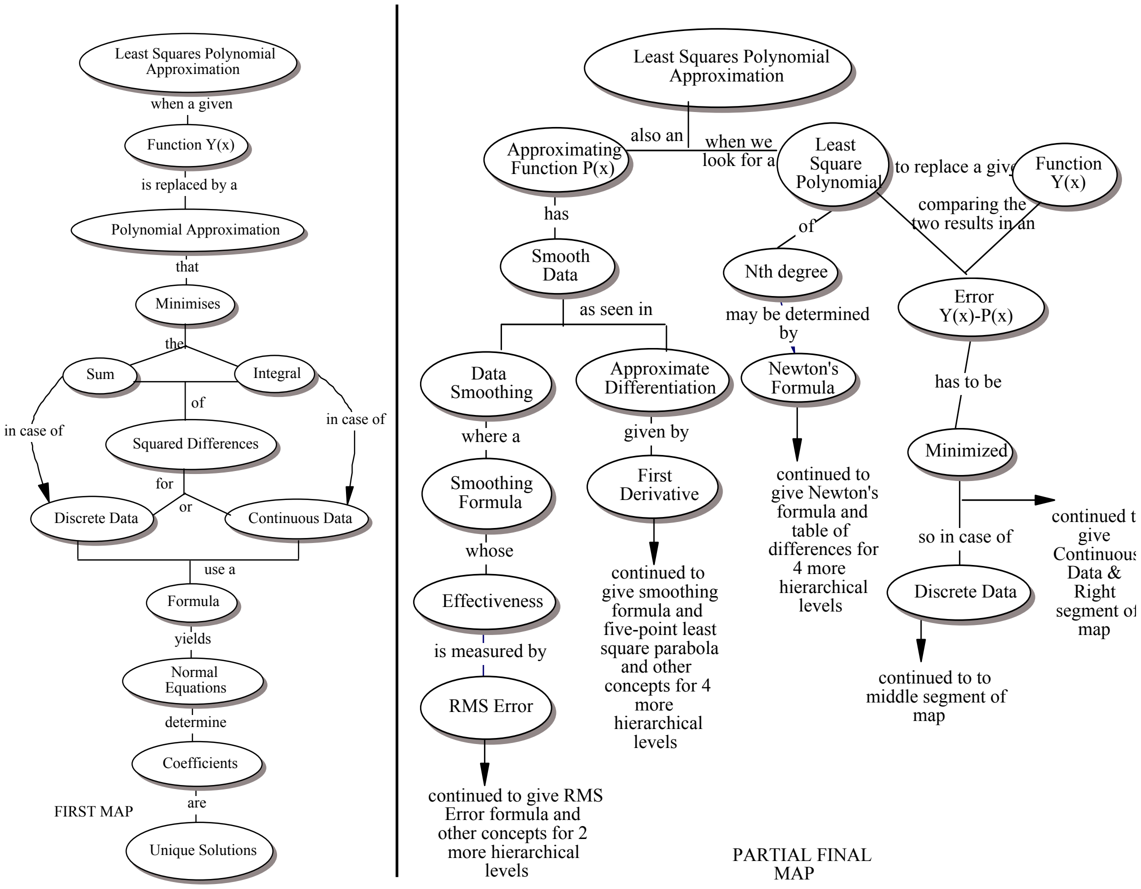

Figure 1. Lou's first concept map & partial final concept map.

2.2 Vee Map Analysis

The structure of the vee diagram (see Figure 2) with its various labels and guiding questions provide a systematic guide to students to reason from the problem context (Event/Object) and given information (Records) in identifying relevant principles, theorems, formal definitions and major rules (Principles) and (Concepts) which can guide the development of appropriate methods and procedures (Transformations) to find an answer (Knowledge Claim) to the (Focus Question). The arrow indicates that there is a continuous interplay between the two sides as students reason through the various sections of the vee. Vee diagrams are qualitatively analysed to determine whether or not the conceptual and methodological sides mutually support each other. That is, do the listed principles support the given solution? Are the listed principles the most relevant for given solution? Is the knowledge claim supported by the listed principles and transformations? As Gowin (1981) points out: "*The structure of knowledge may be characterized (in any field) by its telling questions, key concepts and conceptual systems; by its reliable methods and techniques of work…*" (pp. 87-88).

Therefore, in this study, the vee diagram is used as a tool to not only asses students' proficiency in solving a problem but also the depth and extent of the conceptual bases of this proficiency requiring students to identify the mathematical principles and concepts underlying listed methods and procedures. To these ends, students' vee diagrams are assessed qualitatively in terms of one overall criteria and a more specific one. Specifically, the overall criteria assesses the appropriateness of entries in each section according to the guiding questions in Figure 2 and the given problem whilst the specific criteria refers to the extent of integration and correspondence between listed principles and listed main steps. The focus is on the relevance, appropriateness and completeness of listed principles in relation to methods and procedures listed under Transformations.

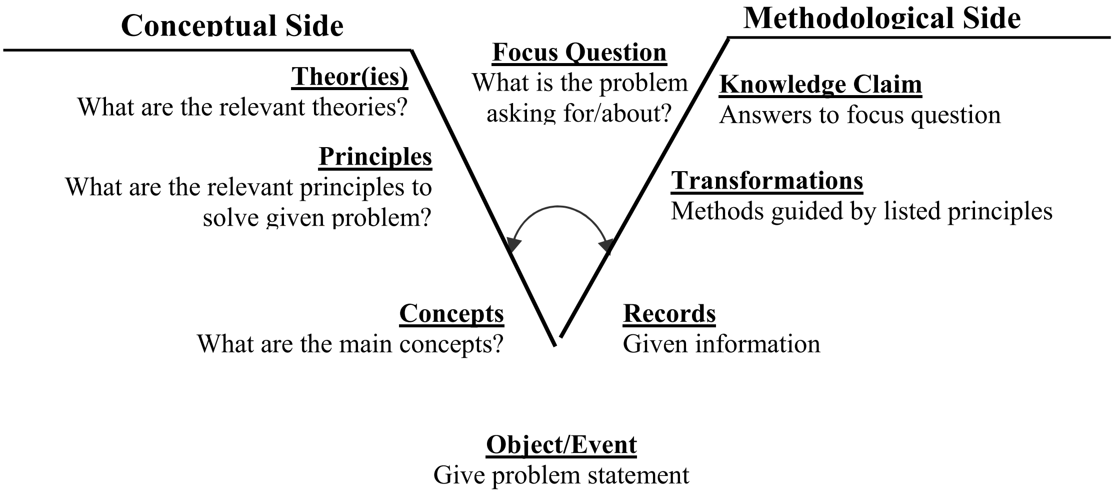

Figure 2. Problem solving vee diagram of mathematics problems (Afamasaga-Fuata'i (1998) modified from Novak & Gowin, 1984, Gowin, 1981)

In consideration of page constraints, instead of presenting each student's vee diagrams, general themes emanating from their work are presented and discussed. For example, in terms of the overall criteria, all students had satisfactory entries for the sections "Theories", "Concepts", "Records", and "Knowledge Claim" as these were basically extracted and inferred from the problem statements. Also because they were free to select their problems, obtaining the correct answers was not problematic. However, what caused a lot of critical comments and numerous revisions were the inappropriate entries for the sections on "Principles", and "Transformations." The general weakness with the former is the language used to describe principles. The intention is clear but wording were initially too procedural in contrast to theoretical statements of general rules and formal definitions. There was a tendency to provide only formulas without clarifications subsequently leading to ambiguities. With transformations, listed main steps did not always have supporting principles on the vee. In terms of the specific criteria, most of the students scored low in their initial maps. However, with critiques, evolving comprehensive concept maps, and subsequent revisions over the semester, students' listed principles improved to become more conceptual statements, and the lists expanded to include relevant principles to support listed main steps in the transformation section. As one of the students wrote in the final report: "*the principles section required much thought and reorganising ... my struggle was to ensure the principles were general statements and formula that became tools for solving the given problem.*"

3 Discussion

Learning a new topic and learning to use concept maps and vee diagrams were big demands of students as Lou puts it: "I began my semester of reading a page over and over again, looking at examples and reading the same page one more time, only to realise that I had to reorganize my concepts again. This became my routine for the study of concept mapping: reading, checking, writing, organizing,.., reading, checking, and onwards I went. " However, by the end of the semester, Lou wrote: "it would have been impossible to reach a more comprehensive map without the input from the class and lecturer." All six students found that to construct a map that made sense to the critics, they had to research more, continually revise and re-organize the concept hierarchies. Furthermore, the construction of the vee diagrams was greatly facilitated when based on a comprehensive integrated and differentiated concept map as evidenced by the creation of additional branches on concept maps to illustrate guiding principles for a method on a vee diagram. In doing these activities, students learnt more about the conceptual structure of their topics in more meaningful ways and at a deeper level as well becoming proficient with the relevant methods and procedures. As Lou sums up her experiences: "When I presented my last concept map to class, it dawned on me that I had finally understood what I was struggling to know since the beginning of semester. The words, 'Least square polynomial approximations' no longer threatened me. I could close my eyes and summarize this topic to someone else without a doubt in my head that what I would be saying made sense."

The concurrent use of the two tools in learning about a new topic contributed significantly in highlighting the close correspondence between the conceptual structure of a mathematics topic and its methods. For example, a student wrote: "*With the help of constructive comments from critiques, I was able to work on appropriate vee* *maps that elaborated on the concept map. This was the fundamental role of the vee diagrams – to elaborate on the concepts shown by the concept maps. With this elaboration, I was able to understand the topic even better.*" That is, possessing only a procedural and algorithmic view of mathematics is limiting. Instead, an enriched knowledge of the conceptual bases of methods, and in-depth knowledge of the conceptual structure can motivate students to learn more about their topic. For example, Lou wrote: "*Making sense out of a difficult topic through concept mapping was the miracle that I was enlightened with. In addition to this awesome discovery, I realised that the miracle was endless. That is, I could go on learning more about least square polynomial approximations because there is always more concepts waiting to be discovered, analysed and revised. So concept mapping is also a tool for extending one's knowledge."*

4 Conclusions

Students' progressive concept maps and vee diagrams showed improvement over time as a consequence of group presentations, individual work, peer critique and one-on-one consultations. That is, students' concept maps had evolved over the semester into maps that were more meaningfully integrated and differentiated and more enriching in its conceptual structure. Their vee diagrams showed growth in their correspondence between methods of solutions and listed principles and enhancement of the conceptual integrity of identified principles. The increased structural and conceptual complexity reflected the growth in the extent and depth of students' understanding of the links between theoretical principles and methods of solutions.

The established socio-mathematical norms of critiques and presentations contributed significantly to the developing quality and refinement of students' evolving understanding of their topics. The act of talking aloud (presenting and justifying to peers) required a level of reflection that aided in the problem solving process. Talking aloud has the power to change students' performance (Richards, 1991, p.37) as evident in the evolving maps/diagrams.

One of the value claims from students' perspectives is the self-realization that the construction of maps/diagrams requires and demands a much deeper understanding of interconnections than simply knowing what the main concepts and formulas are. Although time consuming, the construction of maps/diagrams facilitates learning the structure of a topic in more meaningful ways. Furthermore, students realized that the communication of their understanding is more effective if concepts are arranged in a hierarchical order complete with appropriate labels, meaningful links with concise and suitable linking words. Another value claim of the study is the potential of applying the metacognitive tools to other subject areas by the same students. This is succinctly captured by Lou's comments in her final report: "*I was able to apply the theory of concept mapping to my other subjects and found that I became relaxed when confronted with a difficult topic. Then I was rewarded with good marks. Before I learnt of concept maps, my initial response to a difficult subject would be to panic. Then I would try to break the problem down, read, research, memorize, and do all the things an average student does before understanding some of the topic being studied. Now I wish that our high school teachers had taught us about concept mapping. It would have done wonders for me.*"

There are still problematic areas that need attention mainly due to the newness of the tool which students need to overcome with more practice and more time. As one of the students noted, collecting a list of relevant concepts and formulas is one thing but actually figuring out how they should all be interconnected is another. That is the task of determining the most appropriate linking words to concisely describe the nature of the interconnection still requires further improvement. From this study, the 6 students appreciated the utility of the maps/diagrams as means of illustrating conceptual interconnections within a topic and highlighting connection between principles and procedural steps. Students also appreciated the value of the tools in mapping their growing understanding and as means of communicating that understanding to others in a social setting. Findings from this cohort suggest that concept maps and vee diagrams are potentially viable tools for developing a deeper understanding of the structure of mathematics.

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AN UNDERGRADUATE STUDENT'S UNDERSTANDING OF DIFFERENTIAL EQUATIONS THROUGH CONCEPT MAPS AND VEE DIAGRAMS

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Abstract. The paper presents the case of a student (Nat) who participated in a semester long study which investigated the impact of using concept maps and vee diagrams on students' understanding of advanced mathematics topics. Through the construction of concept maps and vee diagrams, Nat realized that there was a need for him to deeply reflect on *what* he really knows, determine *how* to use what he knows, identify *when* to use *which* knowledge, and be able to justify *why* using valid mathematical arguments. He found that simply knowing formal definitions and mathematical principles verbatim did not necessarily guarantee an in-depth understanding of the complexity of inter-connections and inter-linkages between mathematical concepts and procedures. During seminar presentations and one-on-one consultations, Nat found that using the constructed concept maps and vee diagrams greatly facilitated discussions, critiques, dialogues and communication. The paper discusses the results from this case study and some implications for teaching mathematics.

1 Introduction

The use of concept maps and vee diagrams in learning subject matter more meaningfully and more effectively has been the focus of numerous researches (Mintzes, Wandersee & Novak, 1998; Novak, 2002, 1998; Williams, 1998; Liyanage & Thomas, 2002). The author had also studied the use of these meta-cognitive tools in mathematics problem solving by secondary students (Afamasaga-Fuata'i, 1999, 1998) and undergraduate students (Afamasaga-Fuata'i, 2002a, 2001, 2000, 1999). The undergraduate mapping studies (concept map and vee diagram studies) evolved out of a need to seek innovative ways in which Samoan students' mathematics learning can be improved beyond their technical proficiency in applying known procedures and algorithms (Afamasaga-Fuata'i, 2003a, 2003b, 2002b). However, before presenting Nat's data, the following sections provide an overview, conceptual framework, and methodology of the mapping studies. Data analysis is suggested by Ausubel-Novak's theory of meaningful learning (Ausubel, Novak & Hanesian, 1978; Novak & Gowin, 1984), social constructivistic and socio-linguistic perspectives. A discussion of possible influences of the tools and socio-mathematical norms on Nat's progressive understanding of, and efficiency in solving differential equations (D.E.) problems will be followed by recommendations for teaching mathematics.

The mapping studies explored the impact constructing concept maps and vee diagrams (maps/diagrams) has on students' mathematical understanding particularly their fluency with the language of mathematics and efficiency in communicating in a classroom community of mathematics students including the researcher. Ways in which students' mathematical perceptions are influenced as a result of constructing maps/diagrams and publicly communicating that understanding were also examined. Subsequently, new socio-mathematical norms were established to support the communication of students' evolving understanding bearing in mind that these students have been through years of predominantly traditional mathematics learning where discourse is mainly to transmit knowledge and mathematical discussions (inquiry mathematics) recommended by Richards (1991) is not the norm up to this point (Afamasaga-Fuata'i, 2003a, 2003b, 2002b).

2 Theoretical Perspectives

To explain the processes of knowledge construction and meaningful learning, Ausubel-Novak's cognitive theory of meaningful learning guides the study particularly its principles of assimilation and integration of new and old knowledge into existing knowledge structures. The deliberate linking of concepts to relevant existing concepts may be by progressive differentiation and/or integrative reconciliation. Figure 1 shows a partial view of Nat's first concept map in which the concept "$\mathbf{a_0\, dy/dx + a_1\, y = Q(x)}$" is progressively differentiated into two links to connect to concepts "$\mathbf{Q(x) = 0}$" and "$\mathbf{Q(x) \neq 0}$." In contrast, the two concepts "**Function (x, y)**" and "**Integrating Factor**" are integrated and reconciled with the less general concept "**General Solution**." According to this theory, students' cognitive structure should be hierarchically organized with more inclusive, more general concepts and propositions superordinate to less inclusive, more specific concepts and propositions to facilitate assimilation and retention of new knowledge (Ausubel et. al, 1978, Novak, 2002, 1998).

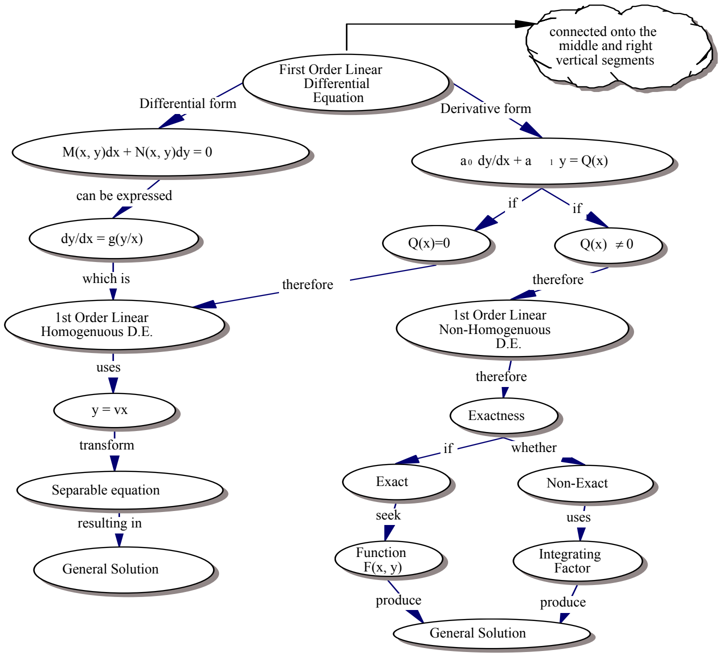

Figure 1. Left vertical segment. Nat's first concept map

The social constructivist perspective provides the opportunity for the development of students' metacognitive skills within a classroom setting particularly as they actively construct mathematical knowledge and reflect on their thinking. Through public presentations, students interact with others as they seek to negotiate meaning, justify and argue the validity of their work. Collectively the cognitive (Ausubel et. al, 1978) and socio-linguistic views (Richards, 1991; Knuth & Peressini, 2001) highlight that "teaching and learning mathematics involves being initiated into mathematical ways of knowing, ideas and practices of the mathematical community and making these ideas and practices meaningful at an individual level" (Ernest, 1999) as well as having the ability to maintain and conduct mathematical discussions (Richards, 1991).

3 Methodology & Data Analysis

The methodology was a qualitative, exploratory teaching experiment (Steffe & D'Ambrosio, 1996) conducted over a semester of 14 weeks with different cohorts to introduce students to the meta-cognitive tools (Novak, 1985). Epistemological principles of building upon prior knowledge, group work, negotiation of meanings, consensus and provision of time-in-class to allow students to reflect on their own understanding guided activities. For example, a familiarization phase introduced students to the new tools and socio-mathematical norms of group and one-on-one (1:1) critiques, including the expectation that students address critical comments from peers and researcher, and then later on critique peers' presented work. Students underwent 3 cycles of group and 1:1 critiques before completing a final report. Topics selected by Nat's cohort of 7 students included partial differential equations, approximation methods, multiple variable functions, Laplace's transform, least square polynomial, and trigonometric approximations. This paper reports the data from Nat's D.E. maps/diagrams. The data for the rest of the 7 students is presented in a second paper for this conference entitled "*Concept maps & vee diagrams as tools for learning new mathematics topics*." Data collected consisted of Nat's progressive concept maps (4 versions) and progressive vee diagrams of 4 problems (at least 2 versions each), and final reports. Students' perceptions of the value of maps/diagrams were obtained through written responses to questions on the advantages/disadvantages of using the maps/diagrams to learn mathematics. In the following sections, Nat's concept map data is discussed first followed by those for the vee diagrams.

3.2 Concept Map Data Analysis

The literature points to different ways of assessing and scoring concept maps (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996; Liyanage & Thomas, 2002) however for this study, a qualitative approach is adopted. Students' concept maps are assessed mainly, using counts, in terms of the *complexity of the network structure* of concepts, *nature of the contents* (entries) within concept boxes (nodes) and *valid propositions,* see Table 1. The structural criteria indicate the depth of differentiation and extent of integration between concepts whilst the contents criteria reflect the nature of students' perceptions of mathematical knowledge. Valid propositions are formed by connecting valid nodes with suitable linking words (correctly describing the nature of interrelationship); that is, valid (node→linking words→node) triads.

TOPIC: Differential Equations	**First Map**	**Final Map**	**%Increase**
CRITERIA: CONTENTS	**Count**	**Count**	
A: Conceptual Contents - TOTAL A	**45 (86.5%)**	**72 (88.9%)**	**2.4**
Concept Names/Labels	31	27	-13
Concept Symbols/Expressions	4	13	225
Symbols	0	4	
Mathematical Statements/Expressions	8	13	63
Names of Methods	2	6	200
General Formulas/Expressions	0	8	800
Formula Concepts	0	1	100
B: Inappropriate Entries - TOTAL B	**7 (13.5%)**	**5 (6.2%)**	**-7.3**
Procedures	0	1	
Linking Words used in concept boxes	0	2	
Redundant Entries	7	2	
C: Definitional Entries – Parts of definitions - **TOTAL C**	**0**	**3**	
D: Examples - TOTAL D	**0**	**1**	
TOTALS A+B+C+D	**52**	**81**	**5 5.8**
CRITERIA: PROPOSITIONS			
Valid Propositions	33	54	63.6
Invalid Propositions	16	19	18.8
CRITERIA: STRUCTURAL			
Main Branches	8	8	0
Sub-branches	13	17	31
Average Hierarchical Levels per Sub-branch	7	11	57
Integrative Crosslinks - Between (sub-)branches at same level	2	2	
Integrative Crosslinks - Between (sub-)branches at different levels	1	12	
TOTAL CROSSLINKS	3	14	366
Multiple Branching - Progressive Differentiation Links from Nodes at:			
Level 2	5	2	
Level 3	2	3	
Level 4	2,2,2	3	
Level 5		5,2,2	
Level 6	2,2	2,2	
Level 7	2,2	7	
Level 8		2	
Level 9		2	
Level 10		2,3	
Level 14		2	
Total Number of Nodes with Multiple Branching	9	14	56

Table 1: Contents, Propositions and Structural Criteria

The occurrences of lengthy statements (*definitional phrases*) require further analysis to identify concepts. Other types, categorized as *inappropriate entries* such as *procedural* entries are more appropriate on vee diagrams; *redundant* entries indicate students' tendency to learn information verbatim and/or in isolation instead of seeking a better re-organization of concept hierarchy or meaningful integrative crosslinks with the first occurrence of concept; whilst *linking word-type entries* are more suitable as linking words, indicate students' difficulties to distinguish between "mathematical concepts" and descriptive phrases. The data in Table 1 and partial views in Figures 1 to 4 show that there was an overall 2.4% increase in valid nodes compared to an associated 7.3% decrease in inappropriate entries. Specific significant increases were noted with the type *concept symbols/expressions* (225%), *mathematical statements/expressions* (63%), *general formulas/expressions* (800%) and *names of relevant methods* (200%) as Nat tried to enhance the meaning of various vertical segments of the concept hierarchy. Figure 1 shows the segments of Nat's first map that attracted critical comments during the first group presentation. His peers felt that it was not illustrating sufficient information to guide a solution of a D.E. problem. Some comments referred to the inappropriate use of important concepts such as *differential form* and *derivative form* as linking words in the propositions: "First Order Linear Differential Equation" *differential form* "M(x,y)dx +N(x,y)dy = 0" and "First Order Linear Differential Equation" *derivative form* "a_0 dy/dx + a_1 y = Q(x)." Over the semester, in response to critiques and feedback from his peers and researcher, these segments evolved to its final form in Figure 2 which shows a more integrated and differentiated network structure that included 9 more new nodes, much higher average hierarchical levels per sub-branch and approximately twice as many multiple branching nodes.

In terms of the structural criteria, data and partial views in Figures 2 and 4 show that Nat's final map had changed significantly compared to the first one in terms of its structural complexity in spite of the unchanged number of main branches, There was a substantial increase (366%) in integrative crosslinks, predominantly more progressive differentiation at various levels (56% increase in multiple branching nodes), 31% increase in sub- branches, 57% increase in average hierarchical levels per sub-branch, and a significant increase (63.6%) in valid propositions. Some of the changes (compare Figures 3 and 4) showed deletions of nodes (*independent variable*, *dependent variable*), merging of two branches (*second order linear differential equation*, *nth order linear differential equation*) to give a more enriched, differentiated and integrated concept hierarchy as partially shown in Figure 4. Nat's propensity to use linking words that are trivial or procedural detracts, rather than add value to the propositions as succinct statements describing the nature of interconnections. These propositions could be further enhanced mathematically with appropriate revision to the linking words.

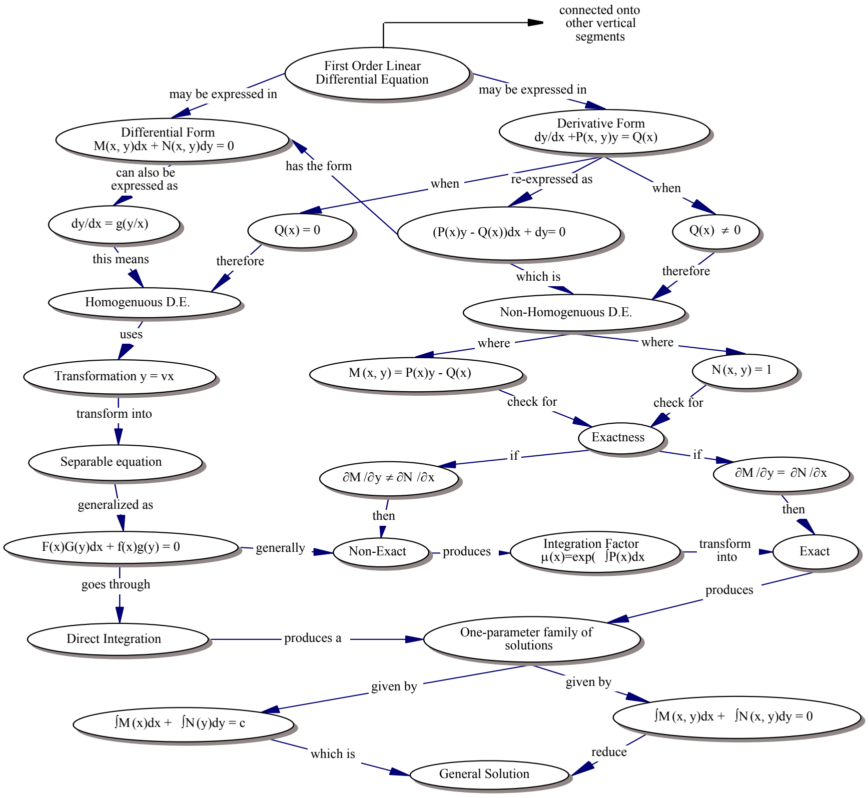

Figure 2. Left vertical segments - Nat's final concept map

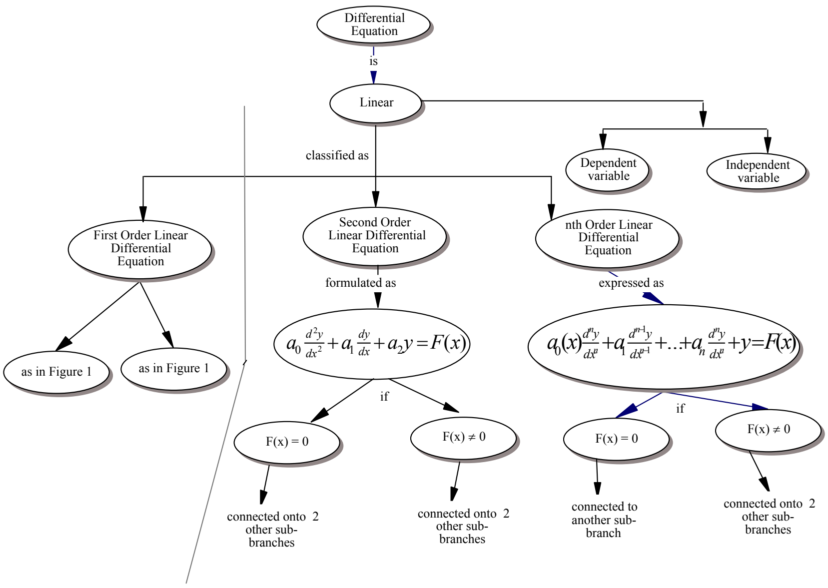

Figure 3. Middle & right vertical segments - Nat's first concept map

3.2 Vee Diagram Data Analysis

The structure of the vee (see Figure 5 for one of Nat's vee diagram) and guiding questions (see Table 2 below) provide a systematic guide to students as they reason from the problem context (EVENT/OBJECT) and given information (RECORDS) to identifying relevant principles, theorems, formal definitions and major rules (PRINCIPLES) and (CONCEPTS) which can guide the development of appropriate methods and procedures (TRANSFORMATIONS) to find an answer (KNOWLEDGE CLAIM) to the (FOCUS QUESTION). As Gowin (1981) points out: "*The structure of knowledge may be characterized (in any field ...) by its telling questions, key concepts and conceptual systems; by its reliable methods and techniques of work…*" (pp. 87-88). Therefore, a vee diagram can be a useful tool for not only assessing students' proficiency in solving a problem but it can assess the depth and extent of its theoretical basis by requesting students to identify mathematical principles and concepts underpinning the methods. Thus vee diagrams are assessed qualitatively in terms of one overall criteria (the appropriateness of entries in each section according to the guiding questions in Table 2 and given problem) and a more specific one (the extent of integration and degree of correspondence between listed principles and listed main steps).

3..1.1 SECTIONS	**GUIDING QUESTIONS**
Theory	What theory(ies), major principles govern the methods?
Principles	How are the concepts related? What general rule, principle, formula do we need to use?
Concepts	What are the concepts used in the problem statement? Relevant concepts required solve problem?
Event/Object	What is the problem statement?
Records	What are the "givens" (information) in the problem?
Transformations	How can we make use of the theories/principles/concepts/records to determine a method?
Knowledge Claim	What is the answer to the focus question given the event?
Focus Question	What is the problem asking about?

Table 2: Guiding Questions for Vee Diagrams of Mathematics Problems

Nat's vee diagrams were drawn after one cycle of group and 1:1 critiques, which means that he was able to use his first revised concept map to guide his vee diagram constructions. The first problem (Figure 5) was on first order whilst the other 3 were all on second order D.E. of type non-homogenous with constant coefficients (P2), homogenous with constant coefficients (P3) and homogenous with variable coefficients (P4). In all four vee diagrams, the common entry under THEORY was "differential equations" with a second one reflecting the general order (n = 1 or 2) of the D.E. A third entry of "homogenous with constant coefficients" was included for P3, and for P4, additional entries were "homogenous" and "power series." For the sections, EVENT/OBJECT, FOCUS QUESTIONS, and RECORDS all entries were appropriate and extracted directly from the problem statements and according to the guiding questions of Table 2. In contrast, Nat's selections of entries under CONCEPTS included others not explicitly in the problem statement but were considered relevant. This means that, Nat already recognizes potential underlying principles, and guided by his revised concept map, he selected the most "suitable" principles, and subsequently relevant concepts, for each vee diagram. For example, in Figure 5, his concept list was: {exactness, derivative, integrating factor, partial differentiation, *initial value* problem, *general solution*, *particular solution*} where 3 of the 7 concepts listed were explicitly stated in the problem statement whilst the rest were inferred as being relevant; similarly, for the other 3 vee diagrams. However, entries for PRINCIPLES required some reflection and consideration. For the first problem, his initial diagram only included 3 of the listed principles. A fourth one was added in the final version when he realized that none of the 3 listed principles justified part v under TRANSFORMATIONS. This was a positive self-realization indicative of a growing confidence in his skills to complete the vee diagram. However, he did not pick up the missing principle underlying the normalization step in part i of the transformations. The rest of the main steps had corresponding principles supporting their transformations. As a presenter of his own work and critic of peers' maps, he was aware that maintaining a close correspondence between principles and main steps of the solution was a critical aspect of, and a common problematic area when constructing a vee diagram.

The specific criteria of a tighter integration and correspondence between main steps and principles calls into consideration the inclusion of relevant principles and the "statement," or "wording" of identified principles. That is, are the listed principles stated in theoretical terms (i.e. formal definitions or general rules) and not as procedural instructions? An inspection of Nat's vee diagrams shows a number of listed principles have the ingredient concepts; however the statements are phrased in procedural or algorithmic terms. For example, in the vee diagram for P3, Nat listed principles (iii) and (iv) as: *"with successful substitution forms: $a_0m^2 + a_1m + a_2 = 0$ which is called 'auxiliary equation'"* and *"roots m_1 and m_2 are obtained after solving the auxiliary equation* *for m"* respectively. These statements are more procedurally worded (*substitution* and *obtained after solving*) than conceptual. This algorithmic nature is also evident in the choice of linking words (*substituted to give*, *must satisfy,* and *check for*) used in the partial segment shown in Figure 4. It appears that his background in computer programming and experience with flow charts are influencing his perceptions of what constitutes appropriate "linking words" and "principles." Alternatively, this procedural view of mathematics suggests that his perceptions of "mathematical knowledge" up to this point may have been predominantly as "a collection of methods and procedures." Thus, in spite of the improvement in aligning the listed principles with main steps of solution in vee diagrams, Nat still needs to rephrase his "procedural" principles to be more theoretical.

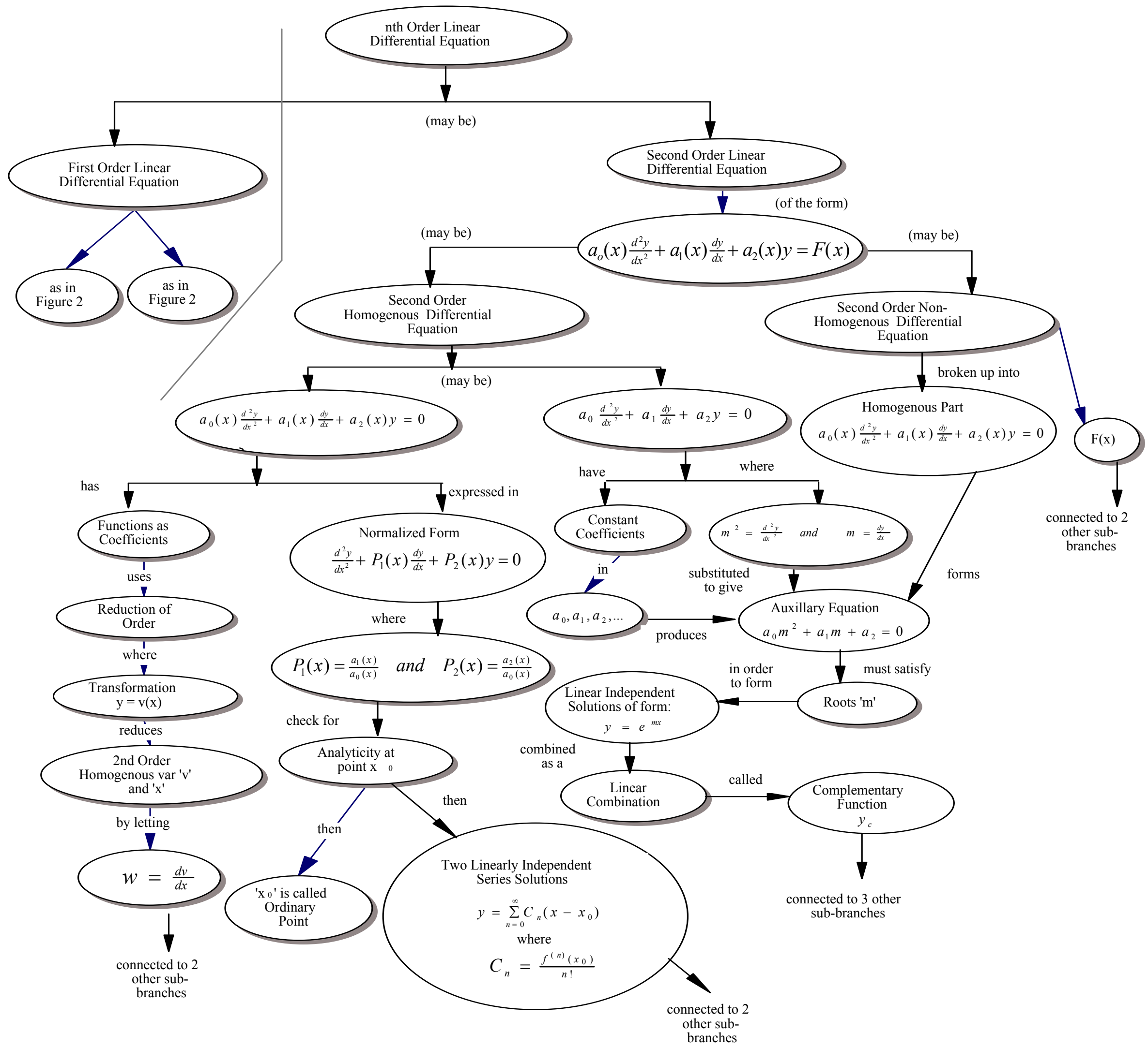

Figure 4. Middle & right vertical segments. Nat's final concept map

4 Summary

Both Nat's final concept maps and final vee diagrams showed significant changes by the end of study compared to his initial attempts. For example, the final map was structurally more complex with increased integrative crosslinks, more progressive differentiation links, additional concepts, and increased number of valid propositions. Evidently, Nat's understanding of differential equations had become more structured, better organized and more enriched to the point that it greatly facilitated the construction of his vee diagrams. For example, he wrote: "*the vee diagram consists of the theoretical and practical senses of the event/object ... directed by the concept map (right segment, Figure 4) flow ... these senses help guide the transformations.*" That is, he was beginning to realize for himself the value of a clearly organized concept hierarchy as a guide to make decisions about effectively solving a problem. Since his vee diagrams were constructed after the first cycle of critiques, they attracted relatively less criticism during critiques unlike his concept maps. From the sociocultural perspective, Nat's conceptual, more structured and better organized understanding of D.E. was partially a result of sustained social interactions, and critiques from his peers and researcher throughout the semester. For example, Nat wrote: "*Due to questions raised in class, on what 'auxiliary equations' represented and how it's formed. Therefore, more details were presented ...*" and "*the whole concept of reduction of order needed clarification in all senses due to its shortened presentation before.*" With reference to two of his vee diagrams, he noted: "*I encountered very little or no critical comment during class presentations ... (so)... I'm left with no urge to make any further modifications ... not criticized at all, therefore no changes.*" That is, his determination to minimize critical comments from others motivated Nat to continually develop a more complete and comprehensive map. For example, he added branches to clarify the concepts: *auxiliary equation, reduction of order* in his second map, and added a new branch in final map to accommodate *power series solutions* (see Figure 4).

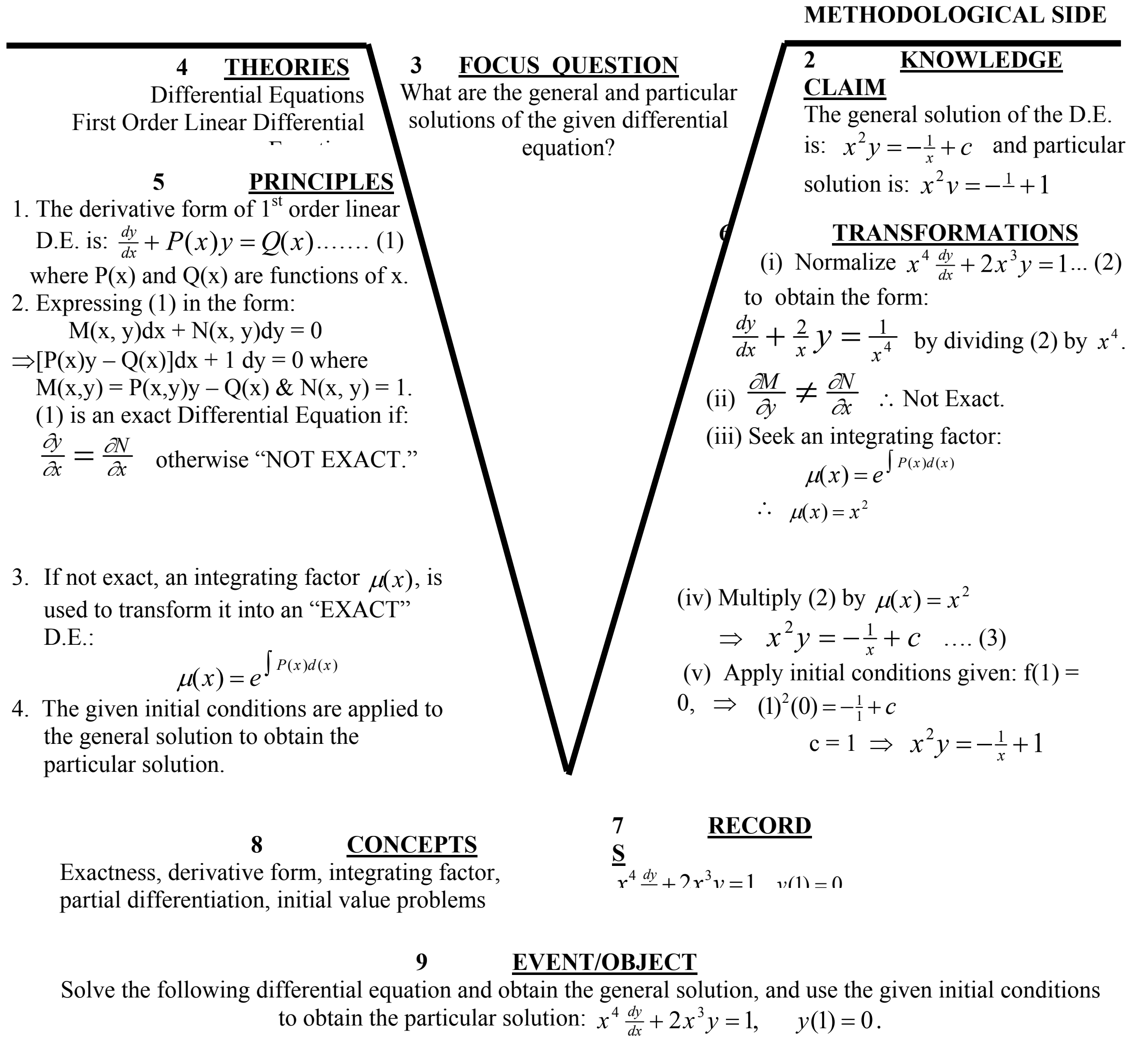

Figure 5. Nat's vee diagram - differential equation problem 1

From the perspectives of Richards (1991) and Knuth & Peressini (2001) Nat and his peers engaged in inquiry mathematics where classroom discourse was both "to convey meaning" and "to generate meaning." Nat, through the use of maps/diagrams engaged in mathematical discussions, dialogues and critiques with his peers and researcher. His fluency with the language of D.E. and the communication of this mathematical understanding publicly was made more effective and efficient with maps/diagrams. There was noticeable growth in Nat's in-depth understanding of D.E. as indicated by the increased number of valid propositions and structural complexity of conceptual networks in his final map, and improved correspondence between listed principles and solutions on vee diagrams. However, because of his tendency to view interconnections and principles with a procedural bias, Nat needs to continuously revise his maps/diagrams over a longer period of time with appropriate critiques and feedback from other mathematics people. Finally, the established socio-mathematical norms, and use of maps/diagrams appeared to promote a classroom environment that was alive with meaningful discussions as students engage in the critiquing and justification processes. Whilst it could be argued that this would happen irrespective of the type of metacognitive tools used, the author proposes that the unique visual structures of the maps/diagrams were pivotal in facilitating and promoting dialogues and critiques. Evidently, the established socio-mathematical norms and use of the metacognitive tools had substantially influenced Nat's perceptions of mathematics as reflected by the progressive improvement in his maps/diagrams. Clearly, with the right supportive classroom environment, students can be encouraged to dialogue, discuss and communicate mathematically. In doing so, students begin to realize that learning mathematics meaningfully involves much more than implementing a sequence of steps. Findings from this case study suggest that students are amenable to changes in classroom practices, and with their cooperation, and using appropriate metacognitive tools, mathematics learning can be made more enriching and meaningful at an individual level.

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EL MAPA CONCEPTUAL: UN TEXTO A INTERPRETAR

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Abstract. El *mapa conceptual* puede ser definido desde la psicología cognitiva como *representación externa*. La diferencia analítica entre *representación interna (mental)* y *representación externa* permite indagar otro tipo características distintas a las implicaciones cognitivas que supone en los sujetos que elaboran dichas representaciones. Las características representacionales y la función del mapa conceptual permiten asociarlo con otros *sistemas de representación*, como son: tablas, gráficos, dibujos y símbolos matemáticos entre otros. Estos sistemas generalmente se relacionan o integran con otra forma de representación: el *texto escrito*. El *mapa conceptual* puede ser leído como externo al texto o como el texto mismo. Considerado como *texto*, el mapa conceptual entra a una esfera pública con procesos históricos y culturales de producción e *interpretación*. Las prácticas de lectura del mapa conceptual *como texto* pueden transformar la práctica de su escritura, dando lugar a nuevas posibilidades representacionales. La *transformación conceptual* del *mapa conceptual* para tratarlo como *texto* permite plantear perspectivas de investigación en el ámbito del *análisis del discurso, literatura, historia, filosofía del conocimiento*, entre otras. El conocimiento en esta perspectiva podría ayudar a comprender, leer y escribir nuevas formas discursivas y nuevos tipos de texto, por ejemplo: *hipertexto e hipermedia*.

1 ¿Son los mapas conceptuales una representación?

Productos culturales y simbólicos como las tablas de información, gráficos, diagramas, mapas geográficos, y otros tipos de esquemas e imágenes, son considerados como *representaciones* (Olson, 1999). El término de *representación* también puede referirse a sistemas representación científica, por ejemplo: las matemáticas, las materiales (maquetas, simuladores), las visuales y las lingüísticas (Ibarra 2003).

Novak y Gowin (1988) hacen referencia a otras formas representacionales, que al igual que los mapas conceptuales, poseen la característica de *representar significados*, estos son: los diagramas de flujo, diagramas de ciclos y árboles de predicados. La función que los autores atribuyen a los mapas conceptuales es la de servir como *herramientas para la representación* (Novak, 1998).

El término de *representación* es utilizado por Novak y Gowin (1988) para describir o definir a los mapas conceptuales, por ejemplo: "Los mapas conceptuales tienen por objeto representar relaciones significativas entre conceptos en forma de proposiciones". Y en otros párrafos, esta vez de Novak (1998): "Los mapas conceptuales desempeñarán una función clave como herramienta para representar los conocimientos del aprendiz y la estructura del conocimiento en cualquier terreno". Y "Los mapas conceptuales son herramientas de representación de los marcos proposicionales y de significado o que se poseen para un concepto o grupo de conceptos". Otros autores utilizan de forma similar el término de *representación*, entre ellos se puede mencionar a: Vitale y Romance (2000), Fisher (2001) y Coffey, *et al.* (2003) quienes consideran los mapas conceptuales como una *herramienta para la representación del conocimiento* que permite producir *representaciones gráficas* del conocimiento (Wandersee, 2001).

Los mapas conceptuales son una técnica de representación con ciertos usos, aplicaciones e interpretaciones previstos y fundamentados en la perspectiva constructivista y la teoría del aprendizaje de Ausubel (2002) (Novak, y Gowin, 1988. Novak, 1988). Otras herramientas de representación tienen origen en disciplinas, teorías o problemas distintos, por ejemplo las herramientas de "pensamiento visual y estadístico" (Tufte, 2000) o las distintas técnicas de representación del conocimiento que desde una postura teórica psicológica específica hacen Jonassen, Beissner y Yacci (1993).

Algunas formas que toman las representaciones son orientadas por la *técnica y tecnología de la representación*. Las *técnicas de representación* sirven para guiar la creación de *representaciones*, dejando de lado, en ocasiones, la necesidad del conocer del trasfondo teórico y filosófico de la técnica de representación para quién elabora una determinada *representación*. Ejemplo de ello es la práctica de la *escritura* durante la cual no todos quienes escriben son *conscientes* de la gramática y la sintaxis y si embargo, se encuentran *implícitas* en cualquier acto escritura. Los *mapas conceptuales* también pueden ser elaborados sin conocer las teorías en las que se fundamenta puesto que la *técnica* integra implícitamente los elementos de la teoría. Ciertas prácticas apoyadas en los mapas conceptuales exigirán mayor conocimiento sobre los fundamentos teóricos mientras que otras podrán darse sin ellas, por ejemplo la *lectura* de los *mapas conceptuales* y su *interpretación* será cualitativamente distinta de acuerdo al contexto de la lectura y los conocimientos que se tengan de la *técnica* como del *tema* que se desarrolla.

El problema de la *lectura e interpretación* del mapa conceptual puede implicar temas relacionados a la evaluación del conocimiento o el aprendizaje, aspectos que se dejarán de lado para abordar al mapa conceptual como *texto*. La idea de *texto* cambia no sólo la *lectura*, que se orienta a la comprensión y no a la evaluación, cambia también la *intención del autor*, pues éste elabora el mapa conceptual para comunicar una idea o construir conocimiento y no para ser evaluado o para *aprender*.

El mapa conceptual, considerado como *texto,* es producto de una actividad intencionada del *autor,* quién con el uso de técnicas de representación, conocimiento y medios de preservación, elabora el mapa conceptual para que sea *publicado y* sometido a la *interpretación* de los *lectores*. Para poder desarrollar esta idea es necesario separar analíticamente la *representación interna (mental)* y la *representación externa*. Esta diferenciación permitirá la explicación del mapa conceptual y sus propiedades representacionales, delimitándola de la explicación psicológica y cognitiva. Esta separación permite la introducción de conceptos como: *autor, texto* e *interpretación* que ayudarán a entender las funciones del mapa conceptual cuando estos son constituidos como textos o como parte de éstos.

2 Representación externa

La *representación* es un concepto utilizado ampliamente en la psicología cognitiva dando lugar a distintas teorías del aprendizaje o de la mente. Según observa Rivière (1986): "La afirmación del carácter representacional de las funciones superiores de elaboración del conocimiento es uno de los axiomas de los enfoques cognitivos en psicología". Problema que reconoce también Perner (1994) quién además refiere la misma apreciación por parte de Fodor y Pylyshyn (1998) y Olson (1988).

Rivière (1986) y Perner (1994) reconstruyen el concepto mediante el análisis de distintas aproximaciones teóricas prestando atención al aspecto *mental o interno* de la representación, dejando de lado, al menos en estas obras en particular, un tratamiento más amplio de la representaciones externas. En contraste, Olson (1999) da atención a las representaciones como aquellos *artefactos* que proporcionan "categorías y formas para la *re-representación* de la experiencia, facilitan ciertos tipos de actividad mental, e inhiben otros", se refiere entonces a las *representaciones externas*. El sistema representacional principal sobre el cual Olson desarrolla su análisis es la *escritura*, pero también refiere a otras representaciones como: la pintura, mapas geográficos (representación del mundo), representación del movimiento (representación matemática), representación de especies botánicas, y representación de situaciones imaginarias. Rivière (1986) proporciona otros ejemplos de representación: "gráficos, mapas, escalar, oraciones y signos". Mientras que Perner (1994) refiere genéricamente a una parte de esta variedad de representaciones como *imágenes*. Estos ejemplos concretos, permiten en un primer momento, considerar por analogía a los mapas conceptuales como representaciones externas. Más adelante se mostrará que tal condición no responde únicamente a similitudes gráficas y visuales, (las características gráficas y espaciales son compartidas por todas las *representaciones externas*) (Pozo, 2003) sino también a sus propiedades (límites) representacionales. La *representación interna*, es un concepto asociado a teorías cognitivas, teorías del aprendizaje y teorías de la mente y es utilizado para explicar procesos de razonamiento (Rivière, 1986) y modelos mentales (Perner, 1994) que al explicitarse utilizando distintos sistemas representacionales (Olson, 1999, Pozo, 2001, 2003), dando lugar a la representación externa.

La terminología que Perner propone es: *medio representacional, contenido representacional y relación representacional*. El *medio representacional* es, de acuerdo al ejemplo que desarrolla el autor, una *imagen*, es decir, un objeto de existencia física que permite *fijar* símbolos, colores, líneas o cualquier otro elemento que permita mostrar o representar algo. El *contenido representacional* es la cosa que aparece o es "representada" en la imagen, y la *relación representacional* es la relación entre la cosa y el contenido representacional.

Para Perner, "*representación"* es el término para referir al *medio representacional* y al *proceso representacional* por lo que en esta perspectiva, la explicación del *medio* requiere necesariamente la explicación del *proceso* en el que es percibida e interpretada una cosa, para seguir esta idea, Perner desarrolla los conceptos de *metarreprensentación y modelos mentales múltiples,* de los cuales no se harán referencia en este documento. El *medio representacional* puede ser un *medio simbólico*, por ejemplo lenguaje e imágenes (Perner,1994). Es esta última acepción de la *representación como medio representacional* es la que más interesa para este artículo.

Siguiendo a Perner (1994) se puede decir que los *medios representacionales* son los *objetos* o artefactos de existencia física o material que sirven para *fijar* símbolos, colores, líneas y letras, entre otros. Estos objetos son producto en parte de *representaciones internas* de los sujetos, su existencia y fijación física y material los hace *externos* al sujeto y por tanto comunicables u observables para otros, en palabras de Olson (1999) las representaciones externas son "artefactos visibles con cierto grado de autonomía de su autor y con propiedades especiales para controlar su interpretación".

Estos artefactos no sólo tienen una existencia material en el sentido físico del término, sino también cobran existencia cultural y simbólica pues se constituyen como *representaciones externas* y *públicas* utilizables para construir nuevas representaciones, es decir, se convierte en a*rtefactos culturales* (Olson, 1999), que no sólo *preservan,* sino que también ofrecen *modelos* para reflexionar acerca la construcción de la representación y posibilitan la creación nuevas representaciones. La construcción de la representación externa implica un proceso de *externalización* de representaciones internas (Pozo, 2001), de esta manera, las *representaciones externas* son un *medio representacional (proceso)* y un *objeto* que da soporte físico que restringe y potencialaza *externalización* y *fija* el producto de esta (Perner, 1994).

Las representaciones externas, como *medio representacional* (soporte, reglas y recursos simbólicos y culturales) y como *proceso de representación,* (redescripción representacional *mediada por artefactos culturales*) (Pozo, 2001), ponen en evidencia la dinámica de *actividad mental* o intención intelectual y la objetivación de estas en *la representación fijada y externalizada*. Esta relación entre lo psicológico y el artefacto cultural ha sido abordada por la psicología cultural lo que ha permitido, entre otras cosas, mostrar que no existe una carácter absolutamente *externo o interno* de los artefactos culturales y que el proceso de *interiorización* es más que la sustitución de funciones (mentales) o lógicas "internas" por reglas y lógicas "externas" (Rivière, 2002). Aunque, como se ha dicho, esta diferencia entre *función interna y externa* no es absoluta ni fija, analíticamente es posible separar el *instrumento psicológico (representación interna)* del *signo externo* (*representación externa)* (Kozulin, 2000, Aguilar Tamayo, 2003). Reconocer el mapa conceptual como signo externo permite indagar los aspectos cognitivos así como reconocer su carácter cultural y simbólico.

Es posible entonces entender el *mapa conceptual* como la representación del *proceso de la actividad cognitiva*, como diagrama que representa *información* o *conocimiento*, y como representación de estructuras de cognitivas con respecto a un tema o dominio. La "fijación" (medio estable de presentación del la imagen) de cualquiera de estas representaciones en cualquiera de los soportes o medios materiales disponibles, implica el uso explícito de la *técnica* de elaboración la cuál implícitamente utiliza símbolos con significados convencionales (líneas que representan conexión, óvalos o círculos que resaltan conceptos, distribución espacial que representa jerarquía, etcétera) (Pozo, 2003).

Pozo (2003) propone cuatro rasgos que permiten caracterizar los *sistemas externos de representación* los cuales se enuncian de manera general: **1** "Los sistemas externos de representación existen como objetos independientes del contexto en que fueron producidos". **2** "Las representaciones externas se basan en un soporte material que les proporciona cierta permanencia". **3** "La mayoría de los sistemas de memoria externa se despliegan en el espacio y no en el tiempo, es decir son sistemas de notación gráfica". **4** "La memoria cultural externa requiere de sistemas de representación con una organización tanto sintáctica como semántica".

De acuerdo a estos rasgos generales con los que Pozo caracteriza a las *representaciones externas*, es posible encontrar lugar para los mapas conceptuales así como para otras representaciones, tales serían los casos del texto escrito, la notación musical, la pintura, diagramas lógico-matemáticos o notación matemática, por mencionar algunas. Las diferencias entre las representaciones mencionadas están asociadas a la *técnica representacional, al soporte y materiales, tecnología de procesamiento* o/y al lugar que ocupan en relación con el discurso científico dominante.

Aquello que se llama *uso y función* de la imagen, tiene que ver con la estructura discursiva dominante en un campo cultural e históricamente determinado, que en el caso de varios de los campos del conocimiento el discurso es primordialmente representado y fijado mediante el *texto escrito*. De esta forma la "figura" o *imagen* será "ilustrativa", "descriptiva" o "descriptiva analítica" (Rodríguez Diéguez, 1996) siempre en función al *texto* que la contiene.

La idea que se mantiene en este artículo es que, además de las funciones del mapa conceptual como *imagen* externa o lateral al texto, cumple también la función del texto mismo. Esta característica es resultado de una *práctica de escritura* que utiliza el mapa conceptual como medio representacional, más adelante se dará un ejemplo al respecto. Otras representaciones visuales han cambiado también su función al interior del discurso científico, Olson (1999) refiere un ejemplo interesante: "Sólo cuando el dibujo fue coordinado con la descripción científica, como en el trabajo del botanista sueco Linneo en el siglo XVIII, los dibujos botánicos pasaron a ser diagramas, y la botánica se convirtió en una ciencia". El "diagrama" al que refiere Olson, cambia la función de "ilustración" de la representación visual para convertirá en parte de la descripción científica dando lugar a un texto híbrido cuya coherencia depende de la referencialidad interna de *texto e imagen*.

3 El mapa conceptual como texto.

El conocimiento, según Olson (1999), "puede comunicarse de diversas maneras: mediante habla, la escritura, gráficos, diagramas, cintas de audio, vídeos", cada una de estas formas inciden en mayor o menor manera en las representaciones legítimas de conocimiento científico.

Para algunas ciencias y disciplinas las formas de representación del conocimiento pueden diversificarse y adoptar otras formas además de la representación lingüística. Por ejemplo, en las matemáticas, se utilizan símbolos y *diagramas (*que serían el resultado de combinar elementos gráficos con texto). Los diagramas son en algunos casos, parte de demostraciones matemáticas, por lo que no son un elemento externo al conocimiento sino parte de él (Hammer,1995). Sin embargo, la forma de representación de mayor legitimidad para ciertas comunidades científicas es la que se estructura en el *texto escrito.* Sin negar que el *texto escrito* es un sistema representacional que ha permitido conservar y construir el conocimiento, otros autores advierten que es factible considerar otro tipo representaciones como las *visuales,* que resultarían también válidas para la construcción y comunicación del conocimiento (Chaplin, 1994, Emmison y Smith, 2000, Kress, et al. 2000). Otros factores de tipo histórico y tecnológico sirven también para explicar la dominancia del texto escrito, Landow (1995) menciona por ejemplo, que el "prejuicio contra la inclusión de información visual proviene de la tecnología de la imprenta" ya que en sus inicios no existía la posibilidad de integrar imágenes a los textos escritos e impresos.

Considerar el mapa conceptual como *texto* implica entre otras cosas, demostrar que el texto puede estar constituido por algo más que signos alfabéticos y más aún, la posibilidad de que estén *contenidos* en otros objetos distintos a los *libros*. Para Simone (2001) "el libro es el hospedaje físico de un objeto completamente distinto de él mismo; contiene un texto, es decir, un cuerpo discursivo organizado según leyes propias". Esta distinción permite a Simone concentrarse en el estudio del texto y sus transformaciones de acuerdo a las prácticas de lectura. La distinción entre *libro y texto* no significa que sean ajenos, al respecto Chartier (2002) hace ver que "los autores no escriben libros: escriben textos que luego se convierten en objetos impresos" pero es la *presentación* del texto (tipografía, formato de impresión y la forma en que el objeto es producido y apropiado en los espacios sociales y culturales) la que abre en un momento histórico dado, nuevos modos de interpretación.

La escritura permite *fijar* oraciones cuya secuencia y semántica dan *coherencia* al texto (Dijk, 1986). El mapa conceptual utiliza tanto la tecnología alfabética como símbolos de convención social y cultural para fijar oraciones. Las secuencias de las oraciones, a diferencia del texto escrito, no conforman párrafos o estructuras lineales, sino más bien presentan una colección de "rutas de lectura" posibles, que al momento de realizase la lectura se da origen a la secuencia de oraciones. Las oraciones pueden ser analizadas semánticamente y convertirse en objetos llamados proposiciones, lo que permite establecer valores de verdad con respecto a lo que expresan. Esta descripción que se acaba de hacer permite mostrar, aunque sea a un nivel básico y muy general, que el mapa conceptual puede ser interpretado y estudiado como un *texto*. Como se verá más adelante, el *texto* puede estar constituido por otros elementos y símbolos distintos al alfabético, un análisis lingüístico del mapa conceptual dejaría de lado aspectos gráficos que son importantes para su interpretación.

Chartier (2002) y Simone (2001) hacen ver, cada uno en perspectivas distintas, que los *textos* pueden tener una característica diferente a la *escrita*, conservando algunas o todas las características y rasgos de los *textos escritos*, así Simone (2001), establece los paralelismos entre el *texto visual* y el *texto escrito* a partir del análisis de la *estructura*, y destaca elementos característicos y comunes de todos los textos, como son: orden, continuidad y discontinuidad temática, además de reconocer otros elementos que se relacionan en cuanto la forma narrativa de los textos.

Chartier (2002) remite a dos reflexiones importantes. Una de ellas, coincidiendo con Simone, es que el texto puede no ser escrito, ya que como demuestra la *interpretación histórica,* esta puede constituir en *textos* objetos de diversa índole, por ejemplo las representaciones externas ya mencionadas; tablas y gráficos, así como documentos administrativos, o pinturas. Para que estos *materiales-documentos* sean tratados como texto, el historiador debe trazar un contexto de interrelaciones entre los objetos y las condiciones históricas de su producción. La segunda reflexión tiene que ver con la *interpretación del lector*, la acción que ejerce el lector sobre el texto. Hasta el momento se había suspendido la discusión de este elemento para centrar la atención en el *texto en si mismo*, porque es a partir de la *interpretación y el papel del lector* que las opiniones de los autores se diversifican y atentan contra la supuesta "estabilidad" del texto. Para Chartier el "texto es "producido" por la imaginación y la interpretación del lector que, a partir de sus capacidades, expectativas y de las prácticas propias de la comunidad a la que él pertenece, construye un sentido particular", sin embargo, en otro momento advierte que esto ocurre sin olvidar que las formas materiales que contiene el texto contribuyen a "moldear las anticipaciones del lector".

La *lectura* juega un papel fundamental en la definición del texto por lo que *sus características propias* no devienen solamente de su estructura, sino que también se encuentran asociadas a las *prácticas de lectura*. En esto coinciden Olson (1999), Chartier (2002), Simone (2001) y Ricoeur (2001, 2002). Este acuerdo se extiende en autores que sostienen posturas contrarias en lo que respecta *la interpretación,* pero que reconocen la *lectura* como la contraparte o complemento del *texto*, tal sería el caso de Eco (1995), Dijk (1989), Barthes (2001) y Rorty (1995). Como se observa, no es posible avanzar más hacia la definición del texto mientras no se aborde sus contrapartes o complementos: la *lectura* y los procesos de *interpretación* a cargo del lector. De esto se hablará más adelante, por el momento es necesario regresar a la problemática de la *representación*.

4 El mapa conceptual como texto, y el texto como representación.

Para que un mapa conceptual se transforme en texto requiere que el autor lo utilice explícitamente como medio representacional. Será él quien decida "cerrarlo" y "fijarlo" para ser expuesto públicamente, hecho esto, se cumpliría una de las características generales que hacen a un texto (Simone, 2001). Para Olson (1999) la transformación del texto a representación exige más que la codificación de la información mediante la tecnología alfabética, la representación debe servir como medio conceptual para conocer el mundo. La conformación del texto requiere entonces, de la intención del autor, de una estructura que preserve un sentido (coherencia interna del texto) y una práctica de lectura.

Chartier (2002) y Olson (1999), cada uno por sus propios métodos, demuestran que los *cambios* en el *texto* y en la escritura se encuentran vinculados a la *práctica de la lectura*. Si bien, como menciona Simone (2001), la *interpretación* (que es en parte una *forma o condición de la lectura*) no puede modificar la estructura y contenido del texto, si puede darle nuevos sentidos (Chartier, 2002). Esto último puede o no ser coincidente con el *sentido* pretendido por el autor.

El conocimiento y la ciencia pueden ser comprendidos como un proceso de construcción de *representaciones* construidas de otras representaciones (Ibarra, 2003. Pozo, 2001, 2003). La comunicación del conocimiento es realizada por medio de distintos medios representacionales (Olson, 1999). Se ha pretendido en este artículo ubicar el *mapa conceptual* como un sistema de representación que puede ser utilizado para comunicar y representar conocimiento y que su estructura proposicional, junto con el uso símbolos culturales, permiten darle una estructura que lo dotan de sentido y lo configuran como texto. La *lectura* del *mapa conceptual* debe comprenderse, en este sentido, no sólo como un acto psicológico de *comprensión del texto* (que lo es), sino como una *práctica de lectura* que tiene lugar en un espacio y tiempo (Chartier, 2000) caracterizado, entre otras cosas, por la recuperación y construcción de textos visuales, audiovisuales, hipertextuales e hipermediales (Simone, 2001. Moreno, 2002). La forma en que se *lee* (interpreta) el mapa conceptual puede cambiar, tal como sucedió con el texto escrito (Chartier, 2002. Olson, 1999. Vitta, 2003), la escritura de los propios mapas conceptuales dando lugar a nuevas representaciones, estructuras y funciones y relaciones con otros textos.

4.1 El autor del mapa conceptual como texto

Un mapa conceptual que se hace para ser presentado a otra persona deberá tener mayor consistencia en los convencionalismos de la técnica, la limpieza y el aspecto gráfico, esto le proporcionará "legibilidad" y "presentabilidad" a la obra del autor. Para la persona que elabora el mapa conceptual, éste será en algunos casos, una versión en proceso, y en otros, una versión "terminada", pero en ambos casos tendrá un carácter *privado*. Un mapa conceptual personal o privado que no se ha elaborado con la intención de ser presentado a otros, podría obviar o simplificar información y algunos otros elementos formales que resulta innecesarios para el propio autor, de manera similar sucede con las notas y apuntes que resultan coherentes y significativos para la persona que los realiza, y complicados o enigmáticos para un lector invitado (John-Steiner, 1997). Obviamente existirán personas que elaboren mapas conceptuales de carácter personal o privado, y que estos cumplan con todos los elementos para ser plenamente comprensible para otros.

Considerando lo anterior, asumir el papel de *autor* en la elaboración de un *mapa conceptual* que será leído por otro, implica un cambio en la estructura del mapa conceptual privado (en caso de haberse realizado algún tipo de notación o apunte en ese formato). El *autor* requiere de imaginar un lector (Eco, 1995. Aguilar Tamayo, 2002) al cual proporcionarle conceptos significativos y coherencia del *texto* (Eco, 1995. Dijk, 1989). Un mapa conceptual considerado así, deja de ser *tarea*, o un producto de cierta actividad, o evidencia de comprensión, o una manera de evaluar y ser evaluado, para convertirse en texto.

Los mapas conceptuales son parte de los *contenidos* en algunas publicaciones de manera similar como lo son las tablas, gráficos, diagramas y otros tipos de esquemas e imágenes son ahora parte del cuerpo del texto. Un ejemplo interesante sobre el papel que comienza a tomar el *mapa conceptual* como parte del texto se encuentra en el libro de Novak (1998). En este libro se presentan veinticinco mapas conceptuales que exponen y abordan directamente los temas tratados en el texto, los demás mapas conceptuales incluidos tienen un carácter de ejemplo. Lo anterior resulta más notable cuando se compara con el texto publicado años antes por Novak y Gowin (1988) en el cual sólo fueron incluidos dos mapas conceptuales directamente relacionados a los temas tratados, los demás mapas conceptuales de esta última publicación cumplen también la función de ejemplos. Más allá de la especulación del porqué al autor usó de manera más amplia los mapas conceptuales como texto, lo relevante es precisamente, el papel otorgado al mapa conceptual. Este uso del mapa conceptual como texto es diferente a aquellos usos en los cuales son integrados como *organizadores previos, guías de lectura, síntesis* o *ejemplos*. Todas estas modalidades tienen un carácter auxiliar al texto, son incluidas de manera externa y no pertenece al "verdadero" texto o a los "contenidos originales".

4.2 El lector del mapa conceptual

Leer un mapa conceptual como *lector* y no como profesor o investigador, cambia la experiencia de la misma lectura. En una lectura "normal", aquella que se hace para comprender lo que dice el texto, el lector está dispuesto a *interpretar* para conocer el sentido del texto, esto permite obviar ciertas cosas que no son significativas en el sentido global del texto, por ejemplo, si se encuentra un error de ortografía, se asume que es un error tipográfico, si en algún párrafo la explicación se hace densa o confusa, se intenta dar sentido antes de tachar el párrafo por incomprensible (aunque podría hacerse).

Un ejemplo curioso al respecto de la lectura del mapa conceptual *como lector*, puede elaborarse a partir de un error de publicación en un mapa conceptual de Novak (1998:22). En esta edición del libro, se observa la falta de una línea o liga. Por este motivo uno de los conceptos queda "volando" ya que no está conectado con ningún otro concepto o palabra enlace. Esta "falta de ortografía" no hace imposible al lector reconstruir el sentido del mapa conceptual y es el lector quien traza mentalmente la línea faltante. Si se tratara de una lectura para *evaluar* el mapa conceptual, el error de edición, ortográfico o tipográfico dejaría de ser considerado así para convertirse en un error de elaboración, o en una falsa creencia e incluso podría considerarse un descuido del autor en el dibujo del mapa. Leer el mapa conceptual como "lector" permite plantear otras interpretaciones o preguntas importantes en cuanto permite descubrir el sentido del mapa conceptual y "completarlo". Incluso podría el lector no estar de acuerdo con el texto, tachar un pasaje de incoherente, pero difícilmente el mapa conceptual serviría para demostrar una "falsa creencia" en Novak. La consideración del mapa conceptual como *representación-texto* sujeto a interpretación, impone y restringen las estrategias analíticas, y algunas de estas formas de leer tendrán que ser distintas a las utilizadas en la psicología y en la evaluación de los aprendizajes.

4.3 El sentido del mapa conceptual y la acción del lector.

Una manera en que el *mapa conceptual* se convierte en *texto* es la intención explícita del autor de "fijarlo" y hacerlo público. Para ello hará uso de las convenciones técnicas y de los medios de soporte físico. Hecho esto, el *mapa conceptual* se constituye en *texto* disponible a una comunidad para su interpretación. Otra forma de transformar el *mapa conceptual* en texto es mediante la acción del *lector*, este puede valerse de instrumentos metodológicos para establecer relaciones entre representaciones y textos para constituir el *mapa conceptual* como texto a interpretar. Ambas posibilidades de convertir el mapa conceptual en texto no son excluyentes la una de la otra y cualquiera de ellas produce un rasgo característico de todos los textos: la independencia del texto de su creador. Una vez constituido el *texto* el autor pierde el control de las interpretaciones que puedan hacer otros sobre el texto. (Olson, 1999. Eco, 1995. Chartier, 2002, Dijk, 1989. Ricoeur, 2001).

El descubrimiento del *sentido* de un texto es un tema a discusión. La comprensión *literal* del texto no es resultado de una actitud "lógica" frente al texto, sino un proceso histórico de práctica de lectura (Olson, 1999). Si bien es imposible resolver el debate en este espacio, es posible tomar partido de la postura de Eco, (1995) y Ricoeur (2001) y considerar, en palabras de Eco, que "un texto puede tener varios sentidos", y rechazar "la afirmación de que un texto puede tener todos los sentidos". En complemento a lo anterior, Ricoeur advierte que "si es cierto que siempre hay más de una forma de interpretar un texto, no es cierto que todas las interpretaciones sean iguales. El texto presenta un campo limitado de explicaciones posibles".

La *interpretación* puede ser orientada por la estructura del texto que imprime un *sentido*. Pero como se ha mencionado, el *lector* puede establecer *relaciones entre textos,* es decir, construir un contexto, del cual el autor es o no conciente y del cual el texto es o no explícito. De esta forma, aunque no sea alterado el texto como tal, la *interpretación* redescribe la *intertextualidad* y la *referencialidad* del texto, como ejemplo extremo se puede imaginar la interpretación de *aquello que no dice un texto* determinado. Considerando lo anterior es posible pensar dos mapas conceptuales que difieran en su sentido (estructura e intención del autor) y aún así representar "lo mismo" para un lector. Para explicar esto considérese el siguiente caso hipotético:

Un profesor pretende conocer los conocimientos previos de algún alumno, para ello utiliza la técnica de los mapas conceptuales. El mapa conceptual podrá ser producto de cualquiera de los siguientes procesos: *a)* de la elaboración del alumno a petición del profesor, o *b)* de la elaboración del profesor quien lo construye a partir de una entrevista con el alumno. Los mapas conceptuales resultantes de estos procesos, desde la perspectiva psicológica, representan la *estructura cognitiva* del alumno, por lo que es posible evaluar los conocimiento previos que posee con respecto un determinado tema. En este sentido es irrelevante el "autor" del mapa conceptual. Los *mapas conceptuales* se convierten en *texto*, en el primer caso, por acción del lector y, en el segundo caso que se convierte en texto por la *intención* del autor (profesor), que es a su vez el lector inmediato del mapa conceptual.

En el caso hipotético mencionado, los mapas conceptuales representan la misma cosa pero no tienen el mismo sentido. Para que tuvieran ambos el mismo sentido, en el primer caso, el alumno tendría que haber representado explícitamente *su* estructura cognitiva o *sus conocimientos previos* lo que implica conocer aspectos de la teoría de Ausubel (2002) y la forma en que la interpreta Novak (1998) y como partir de ella se construye la técnica de los mapas conceptuales. Esto último posible, pero no considerado en el ejemplo.

5 Conclusiones

Se ha pretendido en este artículo sentar algunos ejes generales para el estudio del mapa conceptual como texto. Esta aproximación se hace necesaria con el surgimiento de formas discursivas distintas a la escrita-impresa, como es el caso del hipermedia e hipertexto y los mismos mapas conceptuales. La práctica de lectura y escritura del mapa conceptual puede escapar hacia esferas distintas a la interpretación psicológica, pretendiendo más la *interpretación del texto* que la *evaluación del autor*.

6 Agradecimientos

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CONCEPT MAPPING FOR SUSTAINABLE DEVELOPMENT

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Abstract. Concept mapping has been used as a tool to monitor and promote meaningful learning, thinking, and acting in courses taught by Professor Mauri Åhlberg since 1989 at the University of Joensuu, Finland. In this paper the use of concept mapping is described in an advanced course that focused on teacher as researcher and developer of her/his own work and its preconditions. During the course university students completing their field practice made observations and collected data. They researched their chosen field school, its curriculum, their own teaching, and their pupils' learning. In this paper we describe one aspect of the data in depth. That is, how sustainable development is promoted in the students' field practice schools according to university students' observations, interviews, and other data they collected. The main points were condensed into concept maps, which comprise the data presented in this report. Students have also performed Vee heuristics on each aspect of their study, but we do not present results of those analyses in this paper. The results seem clear that, at least according to university students' observations, schools in rural Finland use more time and energy to promote sustainable development now than they did previously. This is a good sign for the upcoming United Nation's Decade of Education for Sustainable Development (EfS). The issue is important and there is empirical evidence from concept maps that sustainable development is more important than once thought in rural schools of Finland. We suggest the broader use of concept mapping to promote Education for Sustainable Development. Theoretical reasons based partly on empirical research are provided for this suggestion

1 Introduction

The United Nation's World Summit on Sustainable Development took place in Johannesburg, South Africa (August 26 - September 4, 2002). Twelve years has elapsed since the first Summit in Rio de Janeiro in 1992. According to the United Nations (1992, 36th Chapter of Agenda 21), "Education is critical for promoting sustainable development and improving the capacity of people to address environment and development issues." If education is critical, then teacher education is even more critical. Many questions are raised, including: How have schools promoted sustainable development from 1992 to 2004? How should sustainable development be fostered from 2005 to 2014? Education for Sustainable Development has been an important issue in the Savonlinna Department of Teacher Education at the University of Joensuu, Finland, since 1992. In 1989, Professor Mauri Åhlberg began researching, developing, and instructing teacher education students in the use of concept mapping and Vee heuristics. Åhlberg (1990 – 2004) describes this development in detail. In 1992, concept mapping began to be applied to both monitor and promote Education for Sustainable Development.

The concept mapping tool presented in this paper can be used both by pupils and teachers to evaluate, monitor, and promote their learning, thinking, and acting. In high quality learning there is continual integration of thinking, feeling, and acting. When the learner is operating in this way s/he can create more energy, become more empowered, and become better able to solve individual problems and, possibly, some of the problems of her/his society. If we conceptualize research as an integrated learning process that constructs new knowledge and includes testing and reconstruction, then we may better understand Zeichner (1994; p. 66) who writes that "[m]any people are realizing the tremendous power of teacher research and have joined the teacher research community." This paper draws upon the data collected by pre-service teacher education students as they were trying to learn some of the elements of teacher research while collecting useful data about their field practice schools. Zeichner and Noffke (2001) present further evidence for practitioner research.

The pre-service teacher education students we report on in this paper have been trained to use concept maps and Vee heuristics as tools for investigating their own understanding. Concept maps and Vee heuristics were developed in the 1980s as a powerful form of self-analysis (Novak, 1998; Novak & Gowin 1984). Concept maps and Vee heuristics are not commonly used at any level of education. However, they have withstood both theoretical and empirical testing from 1984 to 2002 (Åhlberg & Ahoranta, 2002). One or both of these metacognitive tools have been applied to EE in Finland (e.g., in the doctoral dissertations of Kaivola, 2000, Pitkänen, 2001, and Äänismaa, 2002). From 1993 to 2002 Åhlberg improved these tools by testing them both theoretically and empirically with his university students and with their pupils (Åhlberg & Ahoranta, 2002). Åhlberg (2001) provided a full account of the value of these research tools.

If we want pupils to learn meaningfully and reflectively, then their teachers ought to first learn how to learn meaningfully and reflectively. That is why it may be important to teach pre-service teacher education students to use such tools in their university studies. In this way, pre-service teacher education students can begin to understand how any teacher can research and develop their own work by collecting reports on their students. Furthermore, the tools we are reporting on here can be used to feed back directly into the process of course review and development. In this paper we describe how student reports, and in particular their concept maps, can be used as data to answer research questions. Although we do not analyze them in detail in this paper, one valuable observation of the Vee heuristic is worth noting: One female teacher education student remarked in the value claims of her Vee heuristic: "*The knowledge I have constructed is valuable, but even confusing. Can a teacher really be responsible in these large-scale issues?*" According to international agreements and theoretical and practical research results, the answer is yes. Teachers, as well other citizens, have the responsibility to promote sustainable development. Åhlberg's (2004) first tentative theory of Education for Sustainable Development and some of the main tools needed to promote it are presented in Figure 1. The improved version of the theory of Education for Sustainable Development (Åhlberg, 2004) highlights the increased importance of culturally sustainable development. It highlights ability, competence, expertise, intelligence, creativity, and wisdom for all aspects of sustainable development. It is the educational core of sustainable development.

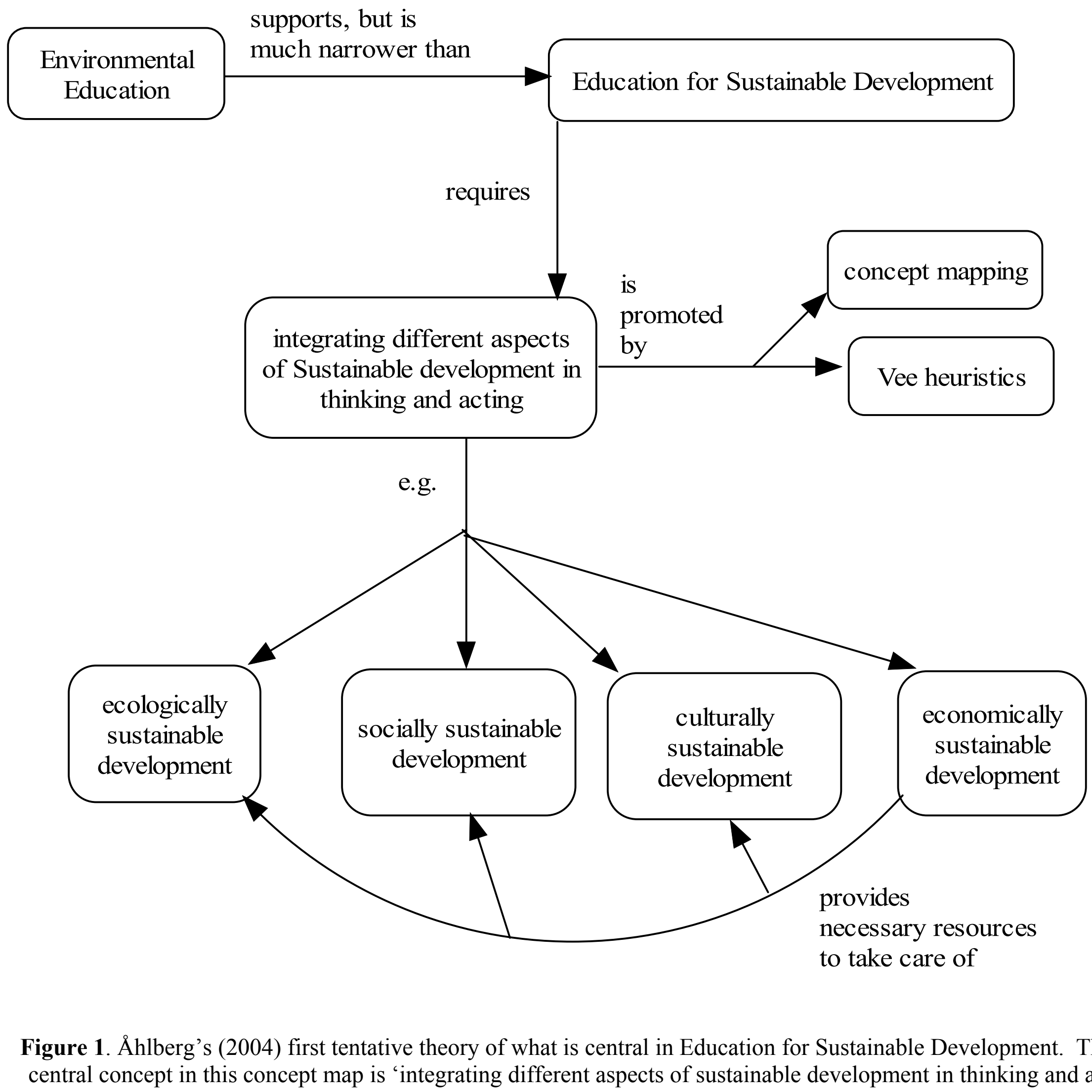

Figure 1. Åhlberg's (2004) first tentative theory of what is central in Education for Sustainable Development. The most central concept in this concept map is 'integrating different aspects of sustainable development in thinking and acting,' because it has more links (7 links) with other concepts than any other concept.

Research question:

What kinds of activities have occurred to promote sustainable development in small rural schools from 1992 – 2003?

2 Methods

Data for this research include university student-constructed concept maps showing how sustainable development was promoted in their field practice school. This report describes a qualitative content analysis of those concept maps. An example of a concept map used as data is shown in Figure 2. There is also an example of a Vee heuristic in Figure 3, but the Vee heuristic data are not discussed in this report. Figure 3 is presented only to show that the Vee heuristic is also a good research method for collecting valuable data. The student teachers' own data is from small country schools. In this paper tentative conclusions are drawn in relation to both the state of sustainable development in small country schools and the student teachers' thinking and learning about sustainable development during their field practice.

The pre-service teacher education students who completed the reports were all over 20 years of age, most of them females. They were in their third year at the University. In the Savonlinna Department of Teacher Education (University of Joensuu, Finland), third year pre-service teacher education students spend a month practicing mainly in small multigrade and multiage schools. During the field practice they gather data about their field practice school, and their own professional development in the school. Small primary schools suitable for field practice are geographically situated all over Finland. They are often rural schools, because multigrade and multiage schools are often located in the countryside. The students themselves suggest the school in which they wish to undertake their field practice and negotiate the required permission to undertake their field practice in that particular school.

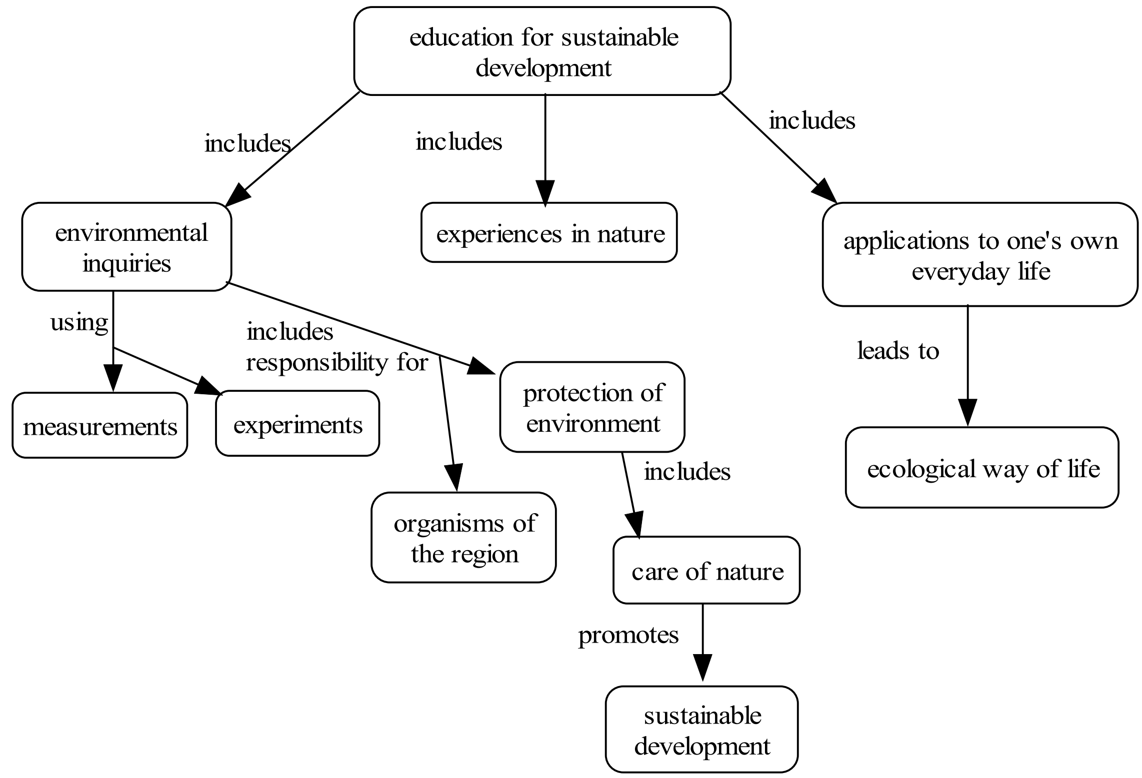

Figure 2. An example of a student-constructed concept map to show how sustainable development was promoted in her field practice school. This concept map is at a very general level. There are much bigger and more detailed ones, but they are harder to translate.

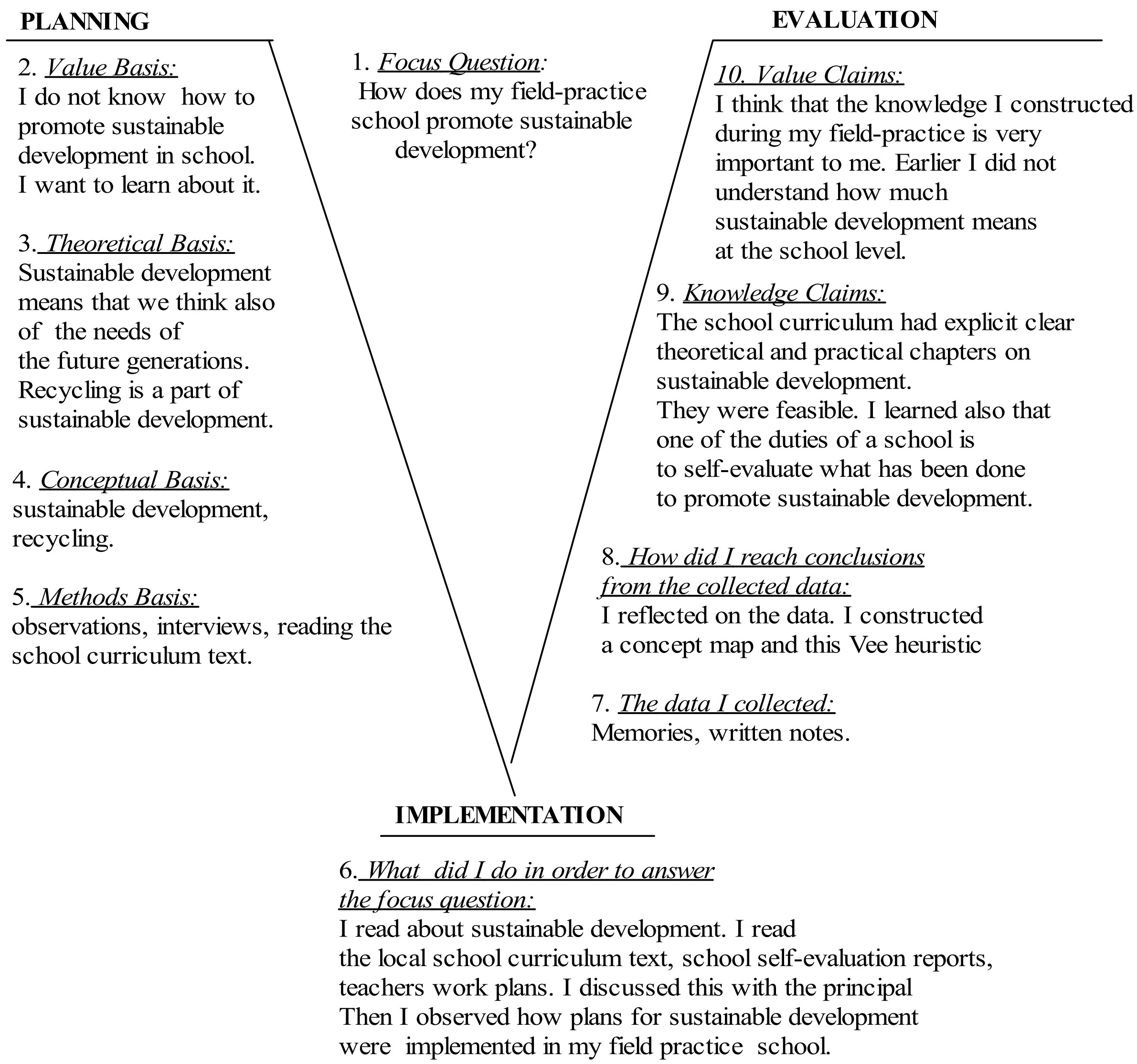

Figure 3. An example of a student-constructed Vee heuristic that shows how these two metacognitive tools are complementary.

3 Results

The small schools in our sample displayed many educational principles. Two of them were equally common: sustainable development as a part of everyday life and nature conservation and protection. The first one is an integrated approach whereas the second one is traditional, not sufficient for EfS, but necessary and important in itself. Respecting/appreciating nature is closely connected to the educational principle of nature conservation and protection. These are examples of promoting ecological sustainability. There are also examples of educational principles fostering social sustainability: good social climate, respecting traditions, good customs and manners, and tolerance, respect of others. These principles probably promote socially sustainable development. Respecting traditions is tricky as a universal principle because some traditional habits may be a barrier to sustainable development. Think, for instance, of eating migrating song birds or of whaling, which are done to preserve old traditions in some countries. Practical activities in the studied schools can be classified into four main types: recycling, sorting, saving, and composting. These are important but relatively easy to learn habits.

There were 30 different reasons mentioned in the reports as to why schools do not promote sustainable development. At first sight the barrier to this most important educational principle was unexpected by us. That the 'curriculum does not include anything about sustainable development' is presented as a barrier to EfS, however, teachers in each school have a responsibility to follow national general curriculum guidelines for Finland. According to these guidelines they should write their own local curriculum document. In the general national curriculum guidelines (Opetushallitus, 1994), it is clearly stated that sustainable development must be integrated into the curriculum. In 1997 the National Board of Education (1997, Opetushallitus, 1997) sent a general letter, in which this theme was raised again: All schools must promote sustainable development. However, the fact that this barrier appears in relation to this most important principle may indicate something about the espoused values of the curriculum as promulgated by central authorities and the actuality of the curriculum as practiced by teachers.

In the concept maps one of the most common barriers of EfS was claimed to be a lack of money. However, Wilska-Pekonen (2001, pp. 248, 287) found that this reason was not reported by the teachers who had undertaken a course of three years in-service environmental education (an EU funded BEENET-project). Prior to the in-service program six out of ten teachers complained about the lack of money, but by the end of the program all reported that lack of money no longer prevented them from delivering EE/EfS. Wilska-Pekonen (2001) reported that the teachers had learned that ordinary everyday life is full of unused possibilities for environmental education and Education for Sustainable Development.

Also, 'threat of closing of the school' was sometimes mentioned on concept maps as a barrier to promoting sustainable development. After discussing this with the student teachers we understand that this threat somehow makes everything new an extra burden to be avoided. Teachers are so stressed about the possibility of the school closing that they do not want to do anything "extra." In their minds promoting EfS is not part of the basic elements of teachers' work. They get their salary without doing it. This is an example of when concept maps alone were not enough. Sometimes you have to ask for more information, however, the concept map was a useful starting point for further inquiries.

4 Summary

This preliminary paper is part of a larger report in progress. It is shown here that concept mapping can provide plenty of important ideas and data for further analysis. In the upcoming United Nation's Decade of Education for Sustainable Development (2005 – 2014) concept mapping is an important metacognitive tool that should be taught broadly to all people. There are good theoretical and empirical reasons why concept maps should be used more widely. With concept mapping it is easy to monitor and promote quality of learning, thinking, and acting. It is a method by which an overview of complex issues such as sustainable development and its main elements can be created.

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A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

SIX YEARS OF DESIGN EXPERIMENTS USING CONCEPT MAPPING - AT THE BEGINNING AND AT THE END OF EACH OF 23 LEARNING PROJECTS

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Abstract. The results of a 6-year period of field testing of concept mapping are described. Very few long-term series of concept mapping experiments have been published. Most publications report very short experiments. Our research was conducted over two 3-year experimental periods, and included partial replications. During each period, two intact school classes with 20 pupils each were tested. The pupils were from grade levels 4 – 6 (10-12 years old). Concept mapping clearly revealed that pupils did learn during each learning project. Number of relevant concepts and number of relevant propositions were used as indicators of meaningful learning. Statistically significant differences between those indicators at the beginning and at the end of learning projects were found for both experimental periods. Pupils were happy to see for themselves that they really learned during the learning projects. Moreover, it seemed to increase their self-esteem and happiness with the teaching-studying-learning process. For the teacher, this was constructivism at its best. She could easily and clearly monitor and promote her pupils' metalearning and metathinking. Qualitative research results of this project include the teacher's observations as well as her tentative theory of the benefits and drawbacks of concept mapping after 6 years of experimenting. Reliability was estimated in the preliminary quantitative analysis. Statistical tests were performed to determine the relationship between the two indicators of meaningful learning and variables including: 1) shared teaching-studying-learning time, 2) sex of pupil, and 3) earlier school achievement levels.

1 Introduction

Very few long-term field experiments with concept mapping have been reported to date. Most published articles describe relatively short-term experiments. The studies presented here, however, were conducted from 1997 to 2003 and longer, with concept mapping incorporated into the experimental design at the beginning, the end, and sometimes even the middle of the learning project. For most teachers, concept mapping is an innovation. The second author of this paper heard about concept mapping only a couple of days before she decided to join this research project and learn to use concept maps. She had no previous conceptions or theory of concept mapping. As mentioned above, concept mapping is often used only for a short experimenting period, which means that we cannot know how things might develop in long-term use. We have not come across any theories of the effect on classroom teachers of using concept mapping. Neither have we seen any research on how much previous school achievement, teaching-studying-learning time, or pupil's sex account for variation in indicators of meaningful learning. As part of this project, however, a tentative theory was constructed by a classroom teacher who participated in our experiments over a 6-year period.

There are different conceptions of what constitutes concept mapping and its indicators of meaningful learning. This paper describes a research project that utilizes a version of concept mapping developed over the years by Ahlberg (1993, 1998, 2001, 2002; Ahlberg, Aanismaa, & Dillon, 2005; Ahlberg & Ahoranta, 2002; Ahlberg, Turja, & Robinson, 2003; see also Ahoranta, 2004). Ahlberg calls it an improved method of concept mapping, and clearly admits that he builds on the work done by Novak and his research group in the United States. However, there are many differences between these two versions of concept mapping. One of the most important differences is that in the improved method of concept mapping, concept maps can also be built from the center outwards. These concept maps are interpreted as pyramids seen from above. It can be easily observed whether or not there is conceptual hierarchy,. which is the only aspect of hierarchies that interests us. We have taken as a starting point the modern cognitive science view that concepts are elements of learning and thinking. Propositions are made out of concepts. That is why we calculate the number of relevant concepts and relevant propositions, and regard them as indicators of meaningful learning. Certainly, conceptual hierarchies are also important, but if, according to modern science the world is thought of as a system, then our best evolving tentative theories of the world have to be conceptual systems. They may not always be hierarchies, but we think that truthfulness of our conceptions is more important than hierarchical presentation.

The research problems this project addresses include:

1) After 6 years of experiments with concept mapping, what kind of theory has the teacher constructed about the benefits and drawbacks of concept mapping?

2) How reliable is long-term concept mapping?

3) How much does:
   a) the shared teaching-studying-learning time
   b) prior school achievement level, and
   c) sex of pupils account for variation in selected indicators of meaningful learning?

2 Methods

Research design and subjects

Two 3-year periods of experimenting produced the data for this 6-year project. In all, 23 learning projects were completed and 46 pupils made concept maps. A total of 920 individual concept maps were collected and analyzed. The data for 9 pupils from each 3-year period were selected for further analysis, and included 414 concept maps. These pupils were partial replicates to each other in many senses.

The school from which these data were collected is an ordinary municipal comprehensive school in Eastern Finland. The classroom teacher who collected these data also used them for her doctoral (PhD) thesis in the Applied Sciences of Education. There were 20 pupils in the first school class. They started at the beginning of fourth grade, at 10 years old. The last concept mapping experiments were done at the end of their sixth-grade year, when they were 12-13 years old. During the 1997 – 1998 school year, individual concept maps were collected from five learning projects. Pupils also completed five learning projects that involved using concept mapping in a similar way, during the 1998 – 1999 school year.. Over the course of the third school year, pupils completed four learning projects in which concept mapping was used both at the beginning and the end of each project. In the second intact school class there were also 20 pupils. During three school years (2000 – 2003), they completed three learning projects per year, for a total of nine projects. Pupils constructed individual concept maps at the beginning and the end of each learning project. Individual Vee heuristics were also constructed in 20 of the 23 learning projects, but the data are not analyzed here. Examples of the data that were collected are presented in Figures 1, 2, and 3.

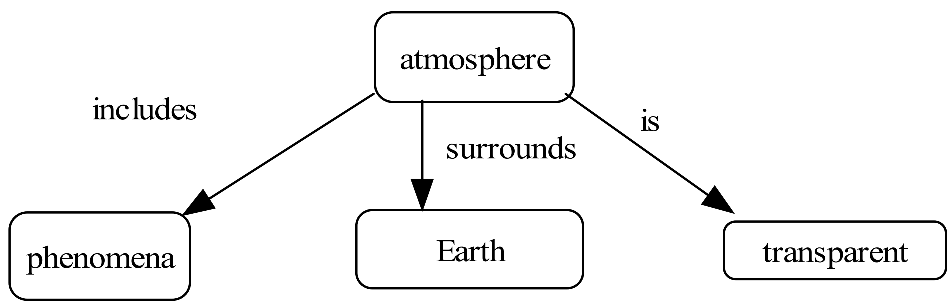

Figure 1. The first concept map completed at the beginning of the experimental unit on Atmosphere, by a male pupil (code:208). The sum of relevant concepts is four, and the sum of relevant propositions is three. 'Atmosphere' is the most central concept because it has more links (3 links) with other concepts than any other concept.

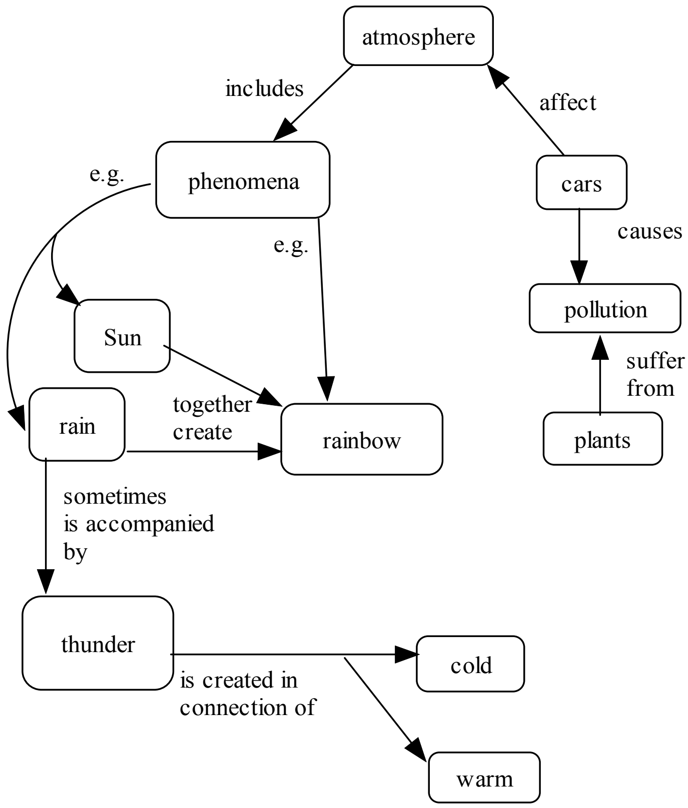

Figure 2. The last concept map completed at the end of the experimental unit on Atmosphere, by the same male pupil (code: 208). The sum of relevant concepts is 11, and the sum of relevant propositions is 12. The most central concept is 'phenomena,' because it has more links (4 links) with other concepts than any other concept.

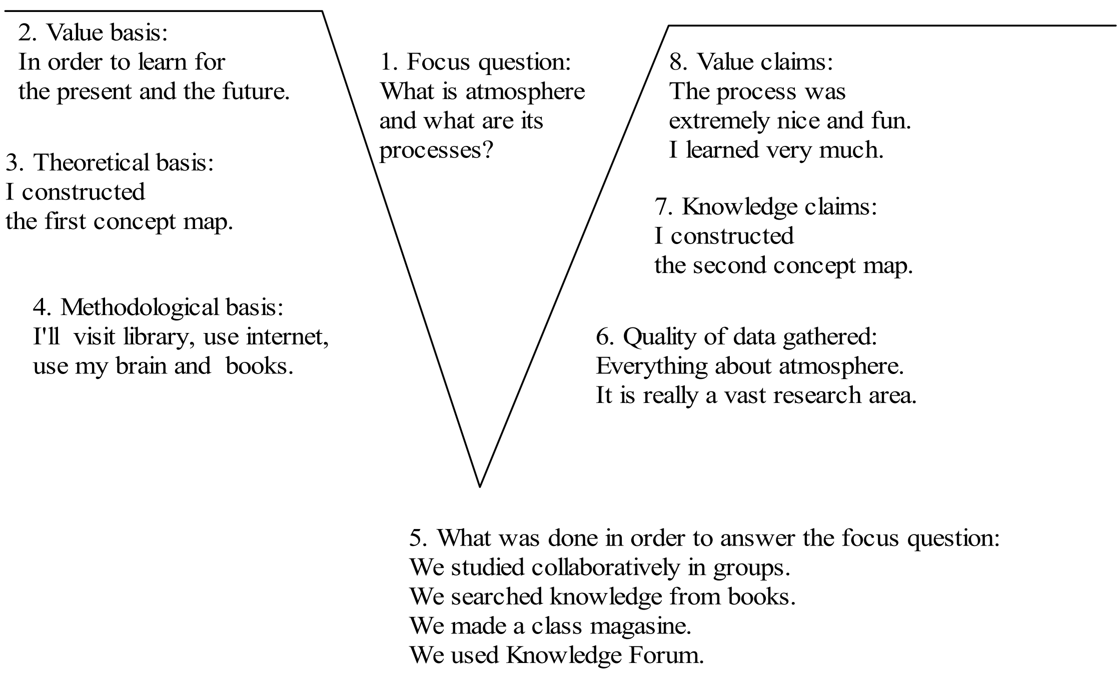

Figure 3. An example of a pupil (code: 208) constructed Vee heuristic from the experimental unit on Atmosphere.

3 Results

Answer to the first research problem: After 6 years of experiments with concept mapping, what kind of theory has the teacher constructed about the benefits and drawbacks of concept mapping?

At the beginning of this research project the teacher who participated had no idea, no conception, and no tentative theory of concept mapping. The ideas below represent the teacher's insights since the start of the project in 1997. The teacher's tentative theory consists of the following propositions:

1. Concept mapping is an excellent way of finding out what pupils have in their metacognition about the theme of a learning project.
2. For pupils it is important to know at the beginning of the learning project what they already know about the theme of the project.
3. The teacher can plan and implement her teaching according to what pupils already know at the beginning of the learning project.
4. The teacher can put pupils into cooperative learning groups based on the results of the first concept maps so that knowledge building in the classroom is facilitated.
5. The teacher understands deeply, broadly, and more clearly what kind of learner each of her pupils is. Concept mapping is the fastest and most practical way I know to get an overview of what pupils know both individually and as a group.
6. Concept mapping is a good method for both teachers and pupils to avoid rote learning, and to learn and think meaningfully. It promotes collaborative knowledge building, according to my observations.
7. Concept maps are constructed individually in my classroom. Each pupil takes full responsibility for her own learning and thinking. There are times when knowledge is built collaboratively, and there are many kinds of collaborative learning, but in the end concept maps are individual products.
8. When pupils compare their concepts maps from the beginning of the learning project to the end of the learning project, they see clearly how much they have learned. This supports their positive self image as a learner. They feel happy and empowered. At the same time, the teacher becomes more empowered.
9. Concept mapping is a concrete way to demonstrate to pupils just how much they know and learn about themes that are studied at school.
10. Concept mapping is a good tool for assessment of learning.
11. Misconceptions are easily revealed by concept mapping.
12. Constructing concept maps is often an enlightening experience for pupils. They have deep, positive feelings toward their learning and their concept maps. They see constructivism in practice as they witness an increase in concepts and propositions in their thinking, understanding, and learning.
13. Concept mapping promotes meaningful learning. School learning is no longer rote learning, but understanding the sum as well as its parts, and the contexts in which they are connected.
14. Concept mapping facilitates other kinds of written composition tasks.
15. The teacher can monitor and promote better learning by individual pupils.
16. Constructing concept maps is hard and energy-demanding work. There is an optimal frequency for using concept mapping, however. As with all other methods of monitoring and promoting learning, if it is used too often pupils become bored.
17. Concept mapping is a method of learning to learn, which can be used any time it's needed.
18. Constructing concept maps is hard work. Pupils are like most people, who try to avoid hard, intellectual work. Although they do understand the importance of concept mapping from time to time, pupils generally do not ask themselves to construct more concept maps than required by the teacher.
19. Most pupils quickly learn how to construct good concept maps, though some pupils need more help and instructions.
20. Some of the brightest pupils try to include all they know into their concept maps. Then the teacher has to teach them to select only the most relevant items. It is probably a very educative experience for those otherwise advanced pupils.
21. If a pupil has very little or no prior knowledge of the theme, she may feel herself helpless. On the other hand, as the learning project proceeds and she clearly sees how much she has learned, then it does not matter that she did not know it all at the beginning.
22. Individual concept maps can be complemented by constructing also, from time to time, collaboratively constructed concept maps. It seems to promote shared understanding and learning.

Answer to the second research problem: How reliable is long term concept mapping?

From the data collected during the first 3-year research period (1997 – 2000), a total reliability estimate was calculated from the sums of relevant concepts and relevant propositions. The resulting Cronbach's alpha was 0.88 when calculated from raw scores, but 0.96 when standardized scores were used. A large variability was observed in the raw scores, which ranged from a sum of 62 to a sum of 210 relevant concepts. Therefore, the standardized scores were considered to be the best estimate.

A total reliability estimate was also calculated from the sums of relevant concepts and relevant propositions for data collected during the second 3-year research period (2000 – 2003). The resulting Cronbach's alpha was 0.93 when calculated from raw scores, but 0.99 when the standardized scores were used. Again, a very large variability was observed in the raw scores, which ranged from a sum of 49 to a sum of 395 relevant concepts, making the standardized scores the best estimate.

Overall, the reliability estimates were very high. When calculated separately for relevant concepts and for relevant propositions, however, the reliability estimates were a little bit lower as shown in Tables 1 and 2.

Learning projects during 1997 – 2000	Reliability estimates at the beginning of the learning projects	Reliability estimates at the end of the learning projects
Reliability of sums of relevant concepts calculated from pupil's concept maps.	$\alpha = 0.75$ ($\alpha = 0.72$)	$\alpha = 0.87$ ($\alpha = 0.89$)
Reliability of sums of relevant propositions calculated from pupil's concept maps.	$\alpha = 0.76$ ($\alpha = 0.73$)	$\alpha = 0.85$ ($\alpha = 0.87$)

Table 1. Reliability estimates are shown separately for the sums of relevant concepts and relevant propositions at the beginning and at the end of the learning projects during the first 3 years of research (1997 – 2000). The estimates were calculated first from raw scores. Estimates calculated from standardized scores are provided in parentheses.

Learning projects during 2000 – 2003	Reliability estimates at the beginning of the learning projects	Reliability estimates at the end of the learning projects
Reliability of sums of relevant concepts calculated from pupil's concept maps.	$\alpha = 0.87$ ($\alpha = 0.88$)	$\alpha = 0.90$ ($\alpha = 0.93$)
Reliability of sums of relevant propositions calculated from pupil's concept maps.	$\alpha = 0.88$ ($\alpha = 0.89$)	$\alpha = 0.91$ ($\alpha = 0.94$)

Table 2. Reliability estimates are shown separately for the sums of relevant concepts and relevant propositions at the beginning and at the end of the learning projects during the second 3 years of research (2000 – 2003). The estimates were calculated first from raw scores. Estimates calculated from standardized scores are provided in parentheses.

Answer to the third research problem: How much does a) the shared teaching-studying-learning time, b) prior school achievement level, and c) sex of pupils account for variation in selected indicators of meaningful learning?

a) The amount of variation in meaningful learning accounted for by teaching-studying-learning time was calculated as follows. First, a paired samples t-test was performed comparing the sums of relevant concepts and sums of relevant propositions at the beginning and at the end of each learning project. The test showed a statistically significant increase in sums of relevant concepts from the beginning of learning projects (M = 85.44, SD = 17.10) to the end of learning projects (M = 145.44, SD = 44.93), $t(8) = -5.732$, $p = 0.000$ for the 1997 – 2000 research period. The eta squared statistic (.80) indicated a very large effect size, and means that 80

% of the variation of sums of relevant concepts are explained statistically by the shared teaching-studying-learning time variable, from the first concept map to the last concept map of each learning project.

For the 2000 – 2003 research period, a statistically significant increase was also found for sums of relevant propositions from the beginning of learning projects (M = 83.33, SD = 17.20) to the end of learning projects (M = 148.67, SD = 53.10), t (8) = -4.555, p = 0.002. The eta squared statistic (.72) again indicated a very large effect size, and means that 72 % of the variation of sums of relevant propositions are explained statistically by the shared teaching-studying-learning time variable, from the first concept map to the last concept map of each learning project.

b) The amount of variation in meaningful learning accounted for by prior school achievement was calculated as follows. According to prior school achievement, pupils were selected and categorized into three groups that included three pupils of low achievement (Group 1), three pupils of average achievement (Group 2), and three pupils of high achievement (Group 3), for a total of nine intensively studied pupils. A one-way analysis of variance was conducted to explore the impact of prior school achievement on variation of indicators of meaningful learning (sums of relevant concepts and sums of relevant propositions). No statistically significant differences were found for data collected from the first research period (1997 – 2000), indicating that prior school achievement did not statistically account for variation of meaningful learning measured by concept mapping.

For the second research period (2000 – 2003), however, prior school achievement was shown to account for variation of indicators of meaningful learning. Statistically significant differences were found in all four analyses: Sums of relevant concepts at the beginning of the learning projects (F (2, 8) = 9.701, p = 0.013) and at the end of learning projects (F (2, 8) = 6.123, p = 0,036); and sums of relevant propositions at the beginning of the learning projects (F (2, 8) = 9.412, p = 0.014) and at the end of learning projects (F (2, 8) = 8.283, p = 0.019). The effect size estimates (eta squared) were very large, varying from 0.67 – 0.76.

There is no good explanation as to why prior school achievement accounted for variability in meaningful learning in the second 3-year period but not in the first. This shows only that these kinds of analyses should be done separately for each group. The main point is that all pupils learned, as indicated by the concept maps, regardless of prior achievement.

c) A one-way analysis of variance was conducted to explore the impact of sex of pupils on the variation of indicators of meaningful learning (sums of relevant concepts and sums of relevant propositions). No statistically significant differences were found for either research period, indicating that sex of pupils did not account for variation of meaningful learning as measured by concept mapping. In other words, girls and boys learned equally meaningfully by concept mapping.

4 Discussion

There are very few long-term research projects of any innovation, and concept mapping is not an exception. This paper has described some of the main results of a 6-year research and development project in which individual concept mapping was used both at the beginning and at the end of 23 learning projects. Individual Vee heuristics were were also used, but those data are not presented here. Over the course of the research, the teacher who participated developed a tentative theory about what concept mapping means for everyday classroom use in grade levels 4 – 6 (pupils ages 10-12 years). The data show that plenty of meaningful learning occurred between the beginning and the end of the learning projects, and that concept mapping is a sensitive tool that provides a useful method for statistically measuring learning gains. Shared teaching-studying-learning time was found to account for 72-80 per cent of the variation of the selected indicators of meaningful learning. Prior school achievement did not account for variation of meaningful learning in pupils from the first 3-year research period (1997 – 2000), though it accounted considerably for the variation found with the second group of pupils. However, there is no general regularity here. Finally, sex of pupils did not account for variation of indicators of meaningful learning. This is good news, because it shows that both females and males can use concept maps to promote meaningful learning, as indicated by concept maps made at the beginning and at the end of each of the 23 learning projects.

This paper was based on the version of concept mapping that has been developed by Ahlberg (1993, 1998, 2001, 2002; Ahlberg, Aanismaa, & Dillon, 2005; Ahlberg & Ahoranta, 2002; Ahlberg, Turja, & Robinson, 2003), and the empirical data presented in Ahoranta's (2004) doctoral dissertation.

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ASSESSING STUDENT TEACHERS' UNDERSTANDING OF THE BIOLOGY SYLLABUS THROUGH CONCEPT MAPPING

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Abstract. A concept map is a visual illustration displaying the organization of concepts/ideas and outlining the relationship among or between those concepts. The application of concept map in the teaching and learning process varies depending on the purpose of its usage. Educators/teachers have used concept mapping to present a topic, relate a new topic to the previous topic, investigate/gather students' prior knowledge or even evaluate students' understanding of the lesson or topic. This paper describes the outcome of an exercise carried out with one hundred undergraduates student teachers (preservice teachers) enrolled in a Biology Teaching Methods course, a third year course in a four-year Teacher Education Programme. The students, working in groups of 3 to 4, were assigned to construct a concept map showing their understanding of a part of the form four (grade ten) biology syllabus/curriculum offered in the Malaysian Secondary School System. The concept maps were derived from materials taken from the syllabus, and consisted of scientific concepts as well as the scientific skills and values associated with the chapters and their relationships. The purpose of this assignment was to familiarize the students with the syllabus and to make them understand the scope of the syllabus itself so that these preservice teachers will know what to focus on when they actually teach in the classroom. Through this exercise, not only the students' understanding of the syllabus was revealed but misconceptions among the students on the syllabus and the concept of scientific skills and values were also detected.

1 Introduction.

A concept map is a visual illustration displaying the organization of concepts/ideas and outlining the relationship among or between those concepts (Geller, 2004; Cañas, Coffey, Carnot, Feltovich, Hoffman & Novak, 2003). According to Novak & Gowin (1984), concept maps are representations of organized knowledge in diagrams. The organization of the knowledge can be hierarchical and/or linear (West, Farmer & Wolf, 1991). Jones, Palincsar, Ogle & Carr (1987) categorized three different and common types of concept maps: the spider map, the chain map and the hierarchy maps. There are other types of concept maps such as the hybrids of those three common maps like the hierarchy map that has a spider map as part of it (West, Farmer & Wolf, 1991). The concepts/ ideas in the concept map are linked to one another by lines or arrows or a combination of lines and arrows. Lines denotes the relationship from the upper concepts to the lower concepts whereas arrows denotes the direction of the relationship of the concepts pointed by the arrow (Safayeni, Derbentseva & Cañas, 2003). The chain map is best used in narrating chain of events or describing the steps in a procedure; the spider maps are used to illustrate the many branches of ideas connected to that concept and the hierarchy maps are used in describing the different levels of concepts connected to that main concept.

Studies on the use of concept mapping reveal that it is not only used in educational institutions, but also in business and government The use of concept map extend to a wide span of age group ranging from elementary/primary school children to scientists from NASA (Leake, Maguitman, Reichherzer, Cañas, Carvalho, Arguuedas, Brenes & Eskridge, 2003). A technical report submitted to the Chief of Naval Education and Training in Florida by Cañas, Carnot, Coffey, Feltovich and Novak (2003) described the use of concept mapping in business and government as a tool in capturing knowledge, support of group processes like brainstorming and also serve as a tool in achieving consensus. This is due to the nature of the concept map itself that contain the ideas/concept to be discussed in orderly manner fashioned /arranged by the people involved. Concept map helps the presenter to convey his/her idea /message across to others making communication simpler because concept map provides the 'overall view' or some call it 'the big picture' of the knowledge/ideas concerned.

The use of concept map in teaching and learning is not limited to the traditional classroom but has been expanded to the electronic media and to distance learning (Coffey & Cañas, 2000). The Institute for Human and Machine Cognition (IHMC) had developed CmapTools, an electronic concept mapping tool available publicly for constructing concept maps, acquiring and sharing of knowledge (http://cmap.ihmc.us). Concept map can be used in curriculum planning (Edmonson, 1995, Ferry et al., 1998, Horton et al., 1993 and Novak, 2003) for showing the topics/contents of a course/ programme or used by educator at the beginning of a lesson in introducing a topic to the students. Other uses of concept mapping include tools for learning (Ault,1985, Chmeilewski & Dansereau,1998, McCagg, 1991) and evaluation or assessment (Aidman & Eggan, 1998, Rice , Ryan & Samson, 1998 and Soyibo, 1995).

Concept mapping is an effective tool as visual representation of schema in teacher preparation course (Mason, 1990). Concept mapping can also be used as a tool in capturing students' previous knowledge before starting with a new topic. Once students' previous knowledge is captured, teacher can assess students' misconception (West, & Pines, 1985) and decide on the appropriate constructivist teaching approach to use. As purported in constructivism, students are not 'a blank slate', they make connection or relate their previous knowledge to the new knowledge learnt. Representing knowledge in the visual format of a concept map allows one to gain an overview of the domain of knowledge. Jonasses (1996) argues that students show some of their best thinking when they try to represent something graphically, and thinking is a necessary condition for learning. Concept maps can also be used as assessment tools. The framework of a concept map assessment consists of three items: the task, the format of student's response and the scoring system (Ruiz-Primo & Shavelson, 1996). The task is the demand requiring srudents to provide evidence of their knowledge in a content area. The format for student's response can be paper-and-pencil response (Wallace & Mintzes,1990; Markham, Mintzes & Jones, 1994) where students drew the concept map on a blank page; oral response (Nakhleh & Krajcik, 1991) or computer response (Fisher, 1990) or even filling in the prestructured skeleton map (Anderson & Huang, 1989). Maps will definitely vary from individual to individual. Hence, it is useful to be able to evaluate or assess different maps. Cronin, Dekkers and Dunn (1982) for instance developed an evaluation scheme based on Ausubelian learning principles. Wallace & Mintzes (1990) devised a scoring system whereby scoring is made based on the components involved.

2 Purpose

This paper describes the outcome of an exercise carried out with one hundred undergraduates student teachers (preservice teachers) enrolled in a Biology Teaching Methods course, a third year course in a four-year Teacher Education Programme. Concept mapping is used as an evaluation tool for assessing the students' understanding of biology syllabus for Malaysian schools . The syllabus concerned is the form four/ grade ten biology syllabus. The purpose of this exercise was to familiarize the students with the syllabus and to make them understand the scope of the syllabus itself so that these preservice teachers will know what to focus on when they actually teach in the classroom. Once the teacher understands the scope of the syllabus well, he/she will be able to adjust or manipulate his/her teaching according to the different situations facing him/her. The teacher will be able to give the best examples of the concept involved using the examples most familiar to the students.

Percentage	Items	Sub items
5%	Inclusion of the topics	Four themes: 1.Introduction to Biology (1 chapter) 2.Investigating cell as a basic unit of life (5 chapters) 3.Investigating physiology (2 chapters) 4.Investigating the interrelationship of life and it's environment. (2 chapters)
5%	Proposition on the link	Correct proposition between the concepts
30%	Levels of hierarchy	Each of the chapters in the themes arranged according to the different level of hierarchy in terms of the cellular approach in biology content (the simple/less complex topics to a more complex topics)
30%	Science process skills	observation, classification, measure and using numbers, making inference, predicting, using of time and spatial skill, interpreting data, control the variables, making hypothesis, experimenting and communicating
30%	Values	Appreciate balance in nature, rational, objective, cooperative, responsible, critical & analytic, showing interests in science, honest, hard working

Table 1: Content of the concept map and weightage.

3 Methodology

The sample consisted of one hundred student teachers (100) enrolled in a Biology Teaching Methods course in first semester of 2003/2004 session (June -September 2003). The course is a third year course in a four-year Teacher Education Programme at a university level in Malaysia. Prior to the task, these students were given four hours of lectures on the components of the Malaysian secondary school Biology syllabus for form four (grade ten). They were also given three hours of lecture on concept mapping and futher guidance by the lecturer involved during their construction of the concept map. Students work in groups of three or four : There were 28 groups of students involved in this exercise (16 groups of four students and 12 groups of three students). They were required to construct a concept map from scratch on the Malaysian Secondary School Biology syllabus for form four. The format for student's response is paper-and-pencil response as used by Markham, Mintzes & Jones (1994) and Wallace & Mintzes (1990). Students were encouraged to include other graphics such as symbols or pictures in their concept map. The scoring system used was an adaptation based on scoring system used by Wallace & Mintzes (1990) whereby scoring is made based on the components involved. The topics required to be included in the map are the themes, the scientific skills and the values suitable for each theme involved. The materials were from the lecture notes and also the Malaysian Secondary School Biology Syllabus For Form Four (Kementerian Pendidikan Malaysia, 2001). Time given to complete the task was eight weeks. Scoring is made based on the criteria set for each of the components. 30% is alloted to the levels of hierarchy of the chapters in the theme of the concept map, 5% for the complete inclusion of the topics, 5% for the correct proposition, 30% for the correct/appropriate science process skills in each theme and 30% for the correct/appropriate scientific and noble values associated with the topic. The content of the concept map is summarized in Table 1.

Group	Inclusion of the topics 5%	Levels of hierarchy 30%	Science process skills 30%	Values 30%	Preposition 5%	Total
1	5	20	28	29	5	87
2	5	25	29	28	4	91
3	5	20	15*	28	3	71
4	5	15	10*	28	2	60
5	5	27	30	28	4	94
6	5	17	20	25	1	68
7	5	28	26	26	4	89
8	5	28	15*	25	3	76
9	4	10	20*	20	1	55
10	5	20	20*	25	1	71
11	5	20	15	28	1	74
12	5	29	15*	15	4	68
13	5	20	29	27	2	83
14	5	20	30	30	3	88
15	5	15	20	25	3	68
16	5	26	05	10	4	50
17	5	15	25	15	1	61
18	5	25	27	28	5	90
19	5	25	25	25	1	81
20	5	20	15	15	4	59
21	5	28	16*	20	5	74
22	5	25	16	16	2	64
23	5	15	10	10	4	44
24	5	18	26	25	2	76
25	5	28	15	15	5	68
26	5	25	15	15	5	65
27	5	20	15	05	3	48
28	5	15	28	15	5	68

Note : * denotes misconception

Table 2: The score of each group in each components in the concept map

4 Results and discussion

The results from the analysis of the exercise is summarized in table 2. The results showed that the lowest total score is 44 and the highest total score is 94. The mean (average) total score is 71.11 indicating that on the overall, group performance is good as the score is above 50%. Even the lowest score is above 30% .

The focus on this exercise was on the understanding of the content of the syllabus. Table 3 states the average and the achievement in each compenents on this concept map.

Aspects	Inclusion of the topics	Hierarchy	Science process skills	Values	Preposition
Mean score	4.96	21.39	20.00	19.03	3.28
Achievement percentage	99.2	71.30	66.66	63.43	65.60

Table 3: Mean Score and Achievement Percentage in each components of the concept map.

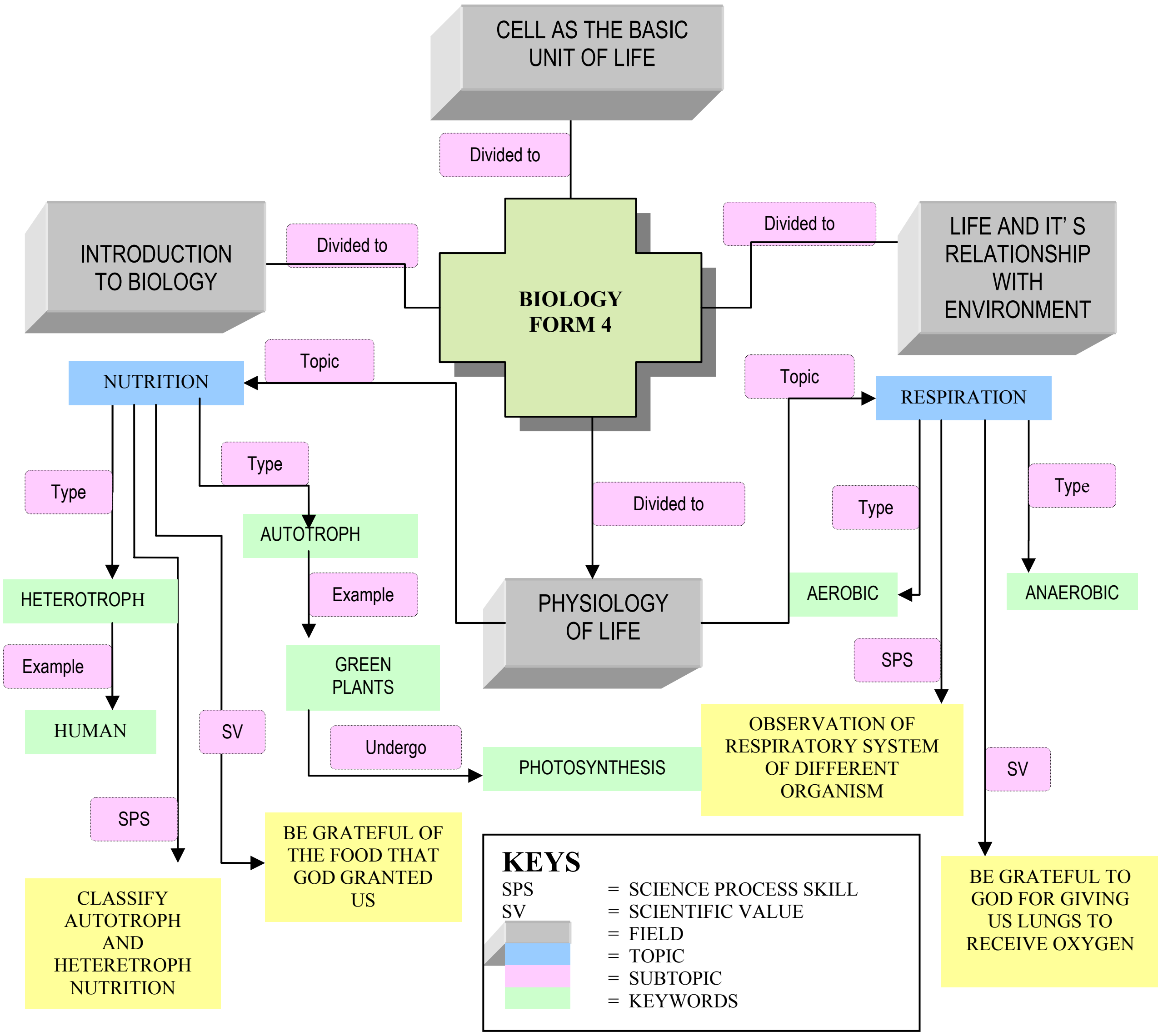

Figure 1. Caption of the concept map of Biology Syllabus for Form Four.

Misconceptions were detected in the area of science process skills. Seven groups showed some misconceptions on science process skills. Thinking skills was stated the same as science process skills. Examples of this misconception is classifying (science process skill) which was stated to be the same as compare and contrast (which is a thinking skill), interpreting data became interpreting concepts, defining operationally was confused as memorizing a set of definitions and observing (a science process skill) is confused as visualizing. Groups that showed misconceptions in the science process skills also did not state the specific science process skills associated with the topics/concepts but only stated the science process skill in general. For example, in the topic of mitosis, the specific science process skill is observing the cells under microscope but the science process skill that was stated was only observation.

The results (Table 3) shows that students knew all the topics involved in the syllabus as the achievement percentage (mean score ÷ weightage) for the inclusion of topics is 99.2%. Students' understanding of the arrangement order of the topics involved in all the chapters is less than the first component (the inclusion of topics) but still high (71.30%). This is followed by their knowledge on science skills (66.66%), the preposition used that showed students' understanding of the relationship of the concepts (65.60%) and the values appropriate for the topics/concepts involved (63.43%). It was noted that groups that scored less in this component (values) not only list just a few values but also stated the value generally without giving specific example. For example, in the topic of Balanced Ecosystem, one of the values that could be imparted through the teaching of the topic is that students should appreciate the balance in nature; not just appreciate God's gift to humankind.

5 Conclusions

This exercise showed how concept mapping can be used to assess the student teachers' understanding of Biology Syllabus. In constructing the concept map, students had to evaluate their own understanding and synthesize the knowledge when they arrange the hierarchy of the topics involved, assigned the preposition on the links and synthesize the specific examples of science skills and values associated with the specific concept/topic. These activities require a high level cognitive performance as identified by Bloom. Through this exercise, students were more familiar with the scope of the biology syllabus and aware of the related scintific skills and values that needed to be integrated in the teaching of Biology in the classrooms. It is hoped that once these student teachers have undergone this concept mapping exercise, they will appreciate and apply concept mapping with their students so that biology is presented in a connected manner and biology learning becomes more meaningful.

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BILINGUAL KNOWLEDGE (BIK-) MAPS: STUDY STRATEGY EFFECTS

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Abstract. The use of bilingual graphic organizers [bilingual knowledge maps (BiK-maps)] as a study strategy was investigated for the acquisition of foreign language vocabulary. Participants were assigned to one of two conditions for the task of studying 32 German-English word-pairs. Participants either used BiK-mapping as a study strategy or took notes in their own preferred style. BiK-map strategists recalled more English words during free recall. Implications for foreign language vocabulary study and future research are discussed.

1 Introduction

The prospect of memorizing lists of foreign language vocabulary (FLV), rarely elicits yelps of pleasure from students. To facilitate the daunting task of learning FLV, researchers, educators, students and entrepreneurs have invented, developed and applied methods that go beyond traditional rote-learning. The present research focuses on one of these methods called bilingual knowledge mapping or BiK-mapping. The introduction of this paper contains a presentation of the following: Connection issues in foreign language (FL) acquisition, the potential of BiK-maps to improve FL acquisition and prior BiK-research.

2 Foreign Language Acquisition: Connection Issues

The goal of rote learning in FLV study is the acquisition of translation knowledge. The type of association between the native and the FL words, necessary to accomplish this objective, is called lexical. FLV learning strategies that go beyond rote memorization are expected to facilitate acquisition, and, to enhance memory by making a variety of contexts available to the learner. Likewise, models of second language acquisition suggest several connections in addition to lexical associations that may be acquired in the process of learning FLV. For instance, Potter, So, Von Eckhardt, and Feldman (1984) propose in their concept-mediation hypothesis that FL words directly access a conceptual, non-linguistic system (1984). Here, a connection a formed directly from the FL word to its meaning. The existence of such semantic or conceptual associations is supported by current research (Altarriba & Mathis, 1997; Fox, 1996). Another possible type of connection forged by novice FL learners emerges from Paivio's dual code hypothesis (1971, 1978) which has been extended to bilingual memory (Paivio & Desrochers,1980; Paivio & Lambert, 1981). Dual coding suggests that learners do not only remember words and their meaning, but also the form, in which the vocabulary was presented. According to Paivio, novice FL learners are able to store visual images in conjunction with FL vocabulary.

If concept and imagic links can be formed during the acquisition of new FL words, one might argue that study materials that incorporate context, such as semantic and conceptual information and images, should lead to benefits by providing additional encoding and retrieval cues. While the addition of image and visuo-spatial cues to FLV appears to be a relatively simple task, the question arises as to how semantic context in the new language can be made more accessible to the novice learner. Initially, the novice learner has only a highly limited FLV and restricted, if any, knowledge of grammar. Without this knowledge, the learner lacks the capability to express and comprehend semantic relationships among new vocabulary items in the FL. The nature of BiK-maps, elucidated in the next section, suggests that they may be uniquely suited to provide context by (a) ameliorating the lack of basic FLV and FL grammar, and, (b) the addition of imagic and visuo-spatial information.

3 The Potential of BiK-maps to improve FL Acquisition

It appears reasonable to consider the degree of connectivity that novice learners are capable of when designing instructional materials and developing learning strategies. BiK-maps are multidimensional, visual representations of knowledge. (See Figure 1 for exemplar.) They resemble flow-charts and consist of *nodes* that encapsulate text or word-pairs, and, *links* (arrows) that connect the nodes. Each link is labeled based on a set of nine link-types, where each type represents a semantic relationship. For example, "P" stands for "part of". (See Figure 1.) Using the simple node-link syntax, text may be transformed into maps, by placing unitary ideas into nodes, and, by connecting them through labeled links. Thus, BiK-maps can provide semantic context without requiring the knowledge of either FLV or grammar. The student with limited knowledge of FLV and grammar can access, or, create their own, semantic context. Moreover, the emergent visuo-spatial properties of maps, apparent in their graphic layouts, may allow for the perceptual organization of knowledge domains. Consequently, BiK-maps could provide encoding and retrieval cues resulting from the spatial organization of their content. The images of the clusters of related ideas, the arrangement of parallel lines of thought, feedback loops, and hierarchies may provide cues for memory storage and search.

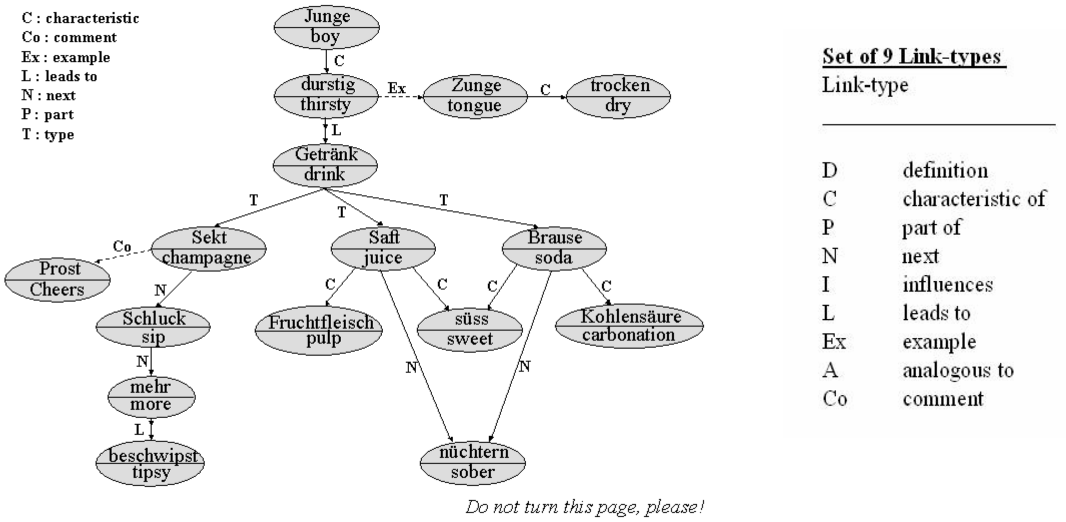

Figure 1. BiK-map exemplar.

3.1 Background on Mapping

BiK-maps are the multi-language version of knowledge-maps (k-maps). Since BiK-maps are a relatively recent addition to the k-map family, the majority of research has been conducted with monolingual materials. For instance, in academic settings, k-maps have been shown to improve the recall of main ideas or macro-structure (e.g., Rewey, Dansereau, and Peel, 1991), to enhance the processing of technical information (Rewey, Dansereau, Skaggs, Hall, and Pitre, 1989), and to benefit individuals with low verbal abilities (Dees & Dansereau, 1993). Training individuals on k-mapping as a study strategy produces a similar pattern of outcomes, e.g., enhanced recall of macro-structure (Rewey, Dansereau, and Peel, 1991). Also, after being trained on k-mapping, trainees spontaneously generate sophisticated annotations when presented with novel study materials (Moreland, Dansereau, and Chmielewski, 1997).

In addition to the research conducted in the academic realm, the k-map approach has been investigated in the area of drug abuse counseling. According to objective measures such as urinalysis, k-maps and -mapping appear to positively impact on the outcome of treatment (Dansereau, Joe and Simpson, 1993, 1995; Dees, Dansereau and Simpson, 1997; Joe, Dansereau and Simpson, 1994). Also, counselors and clients who use k-maps and k-mapping report improved communication and rapport (Dansereau, Joe, Dees and Simpson, 1996; Pitre, Dees, Dansereau and Simpson, 1997). The utility of k-maps as communication interfaces extends to the majority of clients and counselors regardless of cultural, racial or educational differences (Dees, Dansereau, and Simpson, 1997).

In summary, three features of knowledge-maps, their propositional syntax, their visuo-spatial properties and their utility as communication interfaces in counseling, suggest that maps are uniquely suited for multi-lingual applications. The k-map structure represented by arrows and link types, offers the possibility of communicating ideas in two or more languages simultaneously. A bilingual, even multilingual, k-map is constructed by placing more than one language representation of an idea in each node (see Figure 1). The resulting multilingual map could potentially aid international meetings as a communication bridge between speakers of different languages, without the burden of decoding FL vocabulary and grammar. Prior research of relevance to the present study, has explored bilingual k-maps in helping individuals acquire a new language by placing vocabulary to be learned into a coherent spatial and semantic context.

3.2 Prior BiK Research

In previous experiments, students received experimenter produced BiK-maps to study German vocabulary (Bahr & Dansereau, 2001a, 2001b). The initial study (Bahr & Dansereau, 2001a) compared the performance of students who studied BiK-maps to that of students who received the same vocabulary in list format. Two sets (16 word-pairs each) were presented as either maps or lists. Participants were informed that they had 10 min to study each set and that they would be expected to write down the stimuli during testing. The primary memory measures were Free and Cued Recall, which were taken 10 min after the study session had ended. For the *Free* Recall, participants wrote down everything they could remember from the study stimuli. For the *Cued* Recall, participants filled in English translations of FL stimuli. While the Free Recall mean difference approached significance in favor of map students, their Cued Recall performance was significantly higher than that of list learners. *Two essential questions arose from this study:* On a practical level, it remained unclear how durable the immediate recall differences were over time. Additional, delayed recall measures needed to be collected. On a methodological level, we realized that the instructions prior to study did not ensure that learners were attending to the semantic context provided for them in the BiK stimuli. The next study addressed these issues (Bahr & Dansereau, 2001b). Memory measures were taken after a brief delay (as in the initial study) *and* repeated 2 days later. Again, map students performed higher than list students. To address the second question, two groups were added to the original design. With one exception, these groups were identical to the list and BiK-map conditions: In addition to the bilingual stimuli, the new groups were exposed for 30 seconds of the 10 min study time to the stimuli in *English only*. It was hypothesized that initial exposure, limited to native language stimuli, would draw the attention of the participants to the study format and the provided contextual cues. Hence, participants were considered in semantic emphasis conditions. Results indicated that learners with semantic emphasis forgot more vocabulary over time than their non-emphasis counterparts. Apparently, the manipulation created an unexpected memory deficit for foreign language stimuli while the recall performance for native words remained unaffected. In summary, 2 studies investigating the intact BiK-map presentation format, indicate that individuals studying maps compared to lists remember more vocabulary.

3.3 Pertinent Issues and Questions Emerging from Prior Research

3.3.1 Recall Issues

Research on the BiK-map presentation format has reliably demonstrated that BiK-map students recall more vocabulary items than do list learners. Although this finding is encouraging, the possibility could not be ruled out that the delayed recall performance of list and map learners (Bahr & Dansereau, 2001b) was influenced differentially by the immediate recall results. To address this issue the present study employed delayed recall measures without prior immediate tests.

3.3.2 BiK-mapping as a Study Strategy

Another application based on the theoretical background that gave rise to the BiK presentation format studies, is to teach BiK-mapping to FL students as a study strategy. Here, learners create their own BiK-maps from word-pair lists. The question arises whether semantic and visually based elaborations must be produced by experts (as in the BiK-presentation format) to benefit the learner, or, whether learners trained on the production of BiK-maps are able to benefit through the same elaborative mechanisms. It seems reasonable to expect that individuals who employ BiK-mapping as a study strategy with lists of FL vocabulary will engage in deeper processing than individuals who take notes without prior BiK-training. Given the recall-facilitating nature of deep compared to shallow processing (e.g., Lockhart & Craik, 1990; Craik & Lockhart, 1972), it is likely that BiK-mapping individuals will outperform untrained list learners who may or may not attend to and deeply process the context of a vocabulary set. Thus, one might expect a higher performance level from BiK-mappers compared to list-learners unaware of BiK-maps and BiK-mapping.

4 Method

We investigated BiK-mapping as a study strategy in a two group design and evaluated delayed recall performance. Individuals either took notes in their own preferred style or in BiK-map format.

4.1 Participants

The participants were treated according to the APA guidelines. The experiment was reviewed and approved by the Human Subjects Safeguard Committee at Texas Christian University, Fort Worth, Texas. 38 undergraduates were recruited from psychology classes to participate in the study for experimental credit. They were randomly assigned to one of two cells: BiK-strategy (BiK-training and BiK-note-taking during study phase, n = 17), or, Control (Control-training and standard note-taking during study phase, n = 21).

4.2 Materials

4.2.1 Individual Difference Measures.

Participants reported any prior FL education and knowledge of German. Indication of prior knowledge of German was used to screen out overqualified participants. In addition, a processing inventory (PI) regarding textbook study in general (PI-TS) was administered. The PI-TS assesses type and frequency of study strategies used by the participants. In session 2, a multiplication test was administered prior to the study period to detect motivational differences between groups (Chmieleski & Dansereau, 1998). Progress on this test which consists of numerous multiple digit multiplications is hypothesized to be primarily a function of current motivation to perform experimenter provided tasks (Chmieleswki & Dansereau, 1998).

4.2.2 Dependent Variables

The two dependent measures were based on earlier research, which compared the memory performance of BiK-map learners to that of list learners (Bahr & Dansereau, 2001a): The measures collected were *Free* Recall and *Cued* Recall. For the Free Recall (FR), participants were instructed to write down everything they remembered from the study session. This measure yielded two scores: The total number of correct word-pairs recalled, FR-wp, based on 1 point per word-pair, and, the number of English or German words recalled in addition to word-pairs, FR-add, based on 1 point per word. For the Cued Recall (CR), participants received the FL stimuli with the English translations left blank. The student was instructed to write in the appropriate English words. Participants received 1 point for each correct translation.

4.2.3 Study materials

Bilingual lists employed in previous research served as study materials (Bahr & Dansereau, 2001a, 2001b). The number of word pairs was limited to 16 per list, based on research by Crothers and Suppes (1967) who showed that novice learners benefit from learning relatively small groups of words. The types of words chosen were determined by semantic themes reflecting tourist issues abroad (finding and selecting food and drink choices). The average number of syllables for the German words is 1.84 (1.75 in the first set and 1.98 in the second set). The average number of letters per word is 6.56 (6.69 and 6.44).

4.2.4 Training Materials

In session 2, four sets of Hindi-English word-pairs served as training stimuli. The set size was 8 word-pairs for the first two sets and 16 for the third and fourth sets. In the List-training condition all sets were presented in list format. For BiK-map training the first and third set were presented as BiK-maps while the second and fourth set appeared as lists.

4.3 Procedure

The study consisted of three sessions (45 min, 2 hours and 45 min in length, respectively) on a Monday, Wednesday, Friday schedule. The total times given in parentheses are approximations.

4.3.1 Session 1

- Random assignment of participants (15 min)
- Statement of consent administration and collection (10 min)
- Assessment of prior foreign language knowledge (10 min)
- Processing inventory of textbook study (PI-TS) administration (5 min)

4.3.2 Session 2: Training and Study phase

- Training phase (45 min). Individuals were either BiK-trained or List-trained. List-trainees engaged in the same activities and studied the same stimuli as BiK-trainees but were not exposed to BiK-maps or mapping. Prior to the commencement of training, participants received workbooks containing the training stimuli and blank sheets of paper. Stimuli were also presented on an overhead screen as slides of a PowerPoint presentation. The training consisted of two main parts: training warm-up (15 min) and main training (30 min).
- During the warm-up, participants were presented with either a brief written description (List-training), or, a monolingual knowledge map (BiK-training) of a hobby. Then they were asked to write about (List-training) or map (BiK-training) one of their hobbies on a blank sheet of paper for 5 min. Participants were informed, that they would be asked afterwards, to share and discuss their hobby notes, or hobby maps, with a partner. The cooperative activity took 3 min and concluded the warm-up
- During main training, participants continued with the workbooks. Both training conditions were presented with the first of four sets of training word-pairs (Hindi-English). The first set consisted of 8 word-pairs either in list (List-training) or BiK-map format (BiK-training). Participants had 3 min to study these stimuli without taking notes. Next, participants in both training conditions received the second set of 8 word-pairs in list format and were asked to take notes (List-training) or to make a map (BiK-training) based on these stimuli. The note-taking or mapping activities lasted for 5 min. Participants were informed that following this period, they would be asked to share and discuss their notes or maps with a partner. The cooperative activity took 3 min and was followed by the presentation of the third set of stimuli which consisted of 16 word-pairs either in list (List-training) or map format (BiK-training). Participants had 8 min to study these stimuli without taking notes. Next, all participants received the fourth and final set of 16 word-pairs and were asked to take notes (List-training) or to make a map (BiK-training) based on these stimuli. This note taking/mapping activity lasted for 10 min and concluded the training phase of session.
- Study phase (30 min). The materials were administered in the order listed. The multiplication test was timed (4 min). Likewise, exposure to the study stimuli was timed (10 min for each list in the set of two). The study stimuli were presented in list format. Participants were instructed to take notes as they had during the training phase. Map trainees took BiK-notes and Control-trainees took standard notes in their own preferred style. Furthermore, participants were informed that they were going to be tested on the word-pair stimuli in the third session (two days later). After completing the study phase, the experimenter reminded the participants of the time and day of the last session and instructed the students to turn in their folders.

4.3.3 Session 3 (35 min): Collection of dependent measures and conclusion

- Free Recall (15 min)
- Cued Recall (10 min)
- Debrief
- Experimental Credit

5 Results

5.1 Scoring and preliminary analyses

The multiplication-motivation measure from session 2 was included to detect motivational differences prior to the study phase. A one-way ANOVA on the number of problems solved revealed no differences between the groups. Consequently it was concluded that groups were approximately equal in motivation to perform experimenter provided tasks.

Performance on the PI-TS gathered in session 1 served as a covariate. The sum of PI-TS ratings (PI-TSum) served as the frequency-of-use index for a variety of study strategies. The standardized value for Cronbach's coefficient alpha was .627.

The free and cued recall measures were scored with a relaxed spelling criterion. If a word was comprehensible it was considered correct. Inter-rater reliability was established based on a 15% sample ($r = 1.0$). To reduce skewedness, the Cued Recall was capped at 18. The Free Recall of word-pairs, FR-wp, and, the

FR of additional words, FR-add, were each capped at 9. Analyses were conducted with capped and uncapped measures. Capping did not change the results but suppressed univariate interactions that did not reach significance at the multivariate level (Barnett & Lewis, 1984; Keselman, Othman, Wilcox, & Fradette, 2004).

5.2 *Primary analyses*

The primary analyses were conducted with the following measures. The first set consisted of the memory measures, which included the Free Recall scores (word-pairs recalled, FR-wp; words in addition to FR-wp, FR-add), and Cued Recall scores (CR). A 1-way (strategy) MANCOVA on the memory measures revealed a significant effect for strategy $F(3,33) = 3.93$, $p < .016$. A main univariate effect was found for Free Recall of individual words in addition to word-pairs, FR-add, $F(1,35) = 7.31$, $p < .010$. BiK-mappers recalled significantly more English words than control note-takers. Adjusted means and standard deviations in parentheses were: $\text{FR-add}_{\text{BiK-mapping}} = 5.92$ (3.96), $\text{FR-add}_{\text{Control}} = 3.06$ (2.54), $d = .858$; $\text{FR-wp}_{\text{BiK-mapping}} = 2.77$ (3.52), $\text{FR-wp}_{\text{Control}} = 2.18$ (2.63), and $\text{CR}_{\text{BiK-mapping}} = 8.08$ (5.40); $\text{CR}_{\text{Control}} = 8.24$ (5.68).

6 Discussion

The results discussed in this section account for self-reported differences in study strategies.

6.1 *Performance levels*

Research in FL acquisition has been notorious for large standard deviations and relatively low recall scores (e.g., McDaniel & Pressley, 1984; Service & Craik, 1993; Skegan, 1989) Recall percentiles ranged 6.8% to 25.2% for control note-takers and 8.6% to 25.7% for map note-takers. These scores are comparable to performance in other FL vocabulary acquisition studies (e.g., Hogben & Lawson, 1994; Lawson & Hogben, 1998). Still, performance in the current study was lower than the scores in earlier BiK research (Bahr & Dansereau, 2001b). The difference is likely a due to the fact the delayed recall in previous experiments was preceded by immediate recall, which apparently caused a rehearsal effect. The object of the current studies was to eliminate the possibility of differential rehearsal effects. Without rehearsal a consequent suppression of memory in general was unavoidable when testing for BiK-map effects.

6.2 *Primary Findings*

The use of BiK-mapping as a study strategy in the current experiment did not enhance or depress the recall of word-pairs (FR-wp). However, the analyses revealed that BiK-strategists recalled significantly more additional, single words during Free Recall (FR-add) than control note-takers. The majority of the FR-add scores consisted of single native English rather than German, i.e., foreign language, words. Obviously, from a foreign language learner perspective, an increase in additional English words is less desirable than an increase in word pairs consisting of native and foreign language words. However, the availability of additional native words in memory may prove valuable during subsequent study sessions. In the present experiment studying was limited to 20 min total (10 min per set). This constraint is somewhat unrealistic, since foreign language vocabulary words are usually acquired over multiple sessions. In such a scenario the recall of context and fragmented information may very well be advantageous. An experiment that mimics this naturalistic scenario needs to be conducted. It should also be noted that the participants learned and applied the BiK-map strategy in the same session. The novelty of mapping and the inexperience with its application, may have suppressed the learning of word-pairs for mappers compared to their control. Additional practice on mapping may be needed before students can fully realize its potential.

7 Summary

The results from the investigation of BiK-mapping as a study strategy are encouraging but require follow-up. Overall, BiK-mapping appears to facilitate recall, but the type of recall does not indicate an immediate advantage of BiK-mapping over general note-taking. The additional information recalled from the stimuli by BiK-mappers consists of individual words, most of them in English. The recall of such contextual and fragmented information may possibly provide an advantage in subsequent study session when material is being refreshed. Ergo, before concluding on the usefulness of the BiK-strategy, it should be studied in a design that mimics the actual process of vocabulary acquisition (including multiple study sessions) more closely than the current study. An increase in the number of study sessions also ameliorates the lack of familiarity with the mapping technique per se. Continued practice with the opportunity to further annotate and edit self-produced maps is likely to reduce any novelty effects that may affect acquisition and memory.

A continued investigation to fully explore the potential of BiK-maps as connective tissue between the foreign and native language lexica, and, within the FL lexicon, is desirable. So far BiK-maps have performed well as presentation format vocabulary study tools. Empirical research should forge ahead, and (a), examine the utility of the BiK-strategy in reality-based experimental designs, and (b), explore the processing and connection building relevant to BiK-map study by manipulating map parameters.

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THE EFFECT OF COLLABORATIVE KNOWLEDGE MODELING AT A DISTANCE ON PERFORMANCE AND ON LEARNING

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Abstract. This study examines the effect of co-elaborating a knowledge model in dyads at a distance on performance and on learning. Participants (N = 48) were trained to represent knowledge taken from a text, using an object-typed knowledge modeling editor software tool. Knowledge modeling is similar to concept mapping, except that the former is based on a typology of knowledge objects and a typology of links, and that the structure of the knowledge representation is not necessarily hierarchical. After a 75-minute training session to knowledge modeling, each participant constructed a knowledge model individually. The experimental session consisted of elaborating a knowledge model in dyads. In the first condition, participants constructed and shared the knowledge model at a distance, using a whiteboard and a chat tool (synchronous group). In the second condition, participants elaborated one knowledge model with a turn-taking approach; they used e-mail to share their work-in-progress (asynchronous group). In the third condition, participants worked face-to-face at the same computer (control group). Pre- and post-tests were administered to measure learning in the domain. Results show that the quality of the knowledge models was better for dyads in the face-to-face condition than for the ones in the asynchronous condition, but only for the score related to knowledge objects (and not for the score related to propositions). We did not find a significant between-group difference on learning, but results indicate a tendency that working at a distance in a synchronous mode was more beneficial than working face-to-face and synchronously at a distance. These results should be interpreted with caution considering the short duration of the experiment and the low familiarity of participants with the targeted domain and with knowledge modeling.

1 Introduction

The construction of concept maps by learners is an educational strategy whose efficiency has been shown in several studies (Holley & Dansereau, 1984; Horton *et al.*, 1993; Novak & Gowin, 1984; Okebukola & Jegede, 1988). Creating concept maps favors significant learning (Novak & Gowin, 1984), allows learners to define implicit links of various concepts which are often confused by learners (Fisher, 2000), involves learners in deep knowledge-processing (Jonassen, Reeves, Hong, Harvey, & Peters, 1997) and leads them to ''learn how to learn'' (Novak & Gowin, 1984).

Based on socioconstructivist and distributed learning theories, some researchers have started to investigate collaborative concept mapping. They claim that such a strategy triggers discussions and sociocognitive conflicts which are beneficial to learning. Thus, van Boxtel, van der Linden, & Kanselaar (2000) observed a greater number of such discussions with students who constructed collaborative concept maps than participants who produced a poster. Osmundson, Chung, Herl & Klein (1999) also observed buoyant arguments and discussions in small teams of 10-11 year old children who were creating computerized concept maps. Moreover, collaborative concept mapping triggers negotiation of meaning, a critical activity in the learning process (Osmundson *et al.*, 1999). Roth & Roychoudhury (1993) found that co-constructed maps allowed college students to ensure they were discussing the same concepts. Maps also made it easier to express mental representations than spoken language only. Concept maps have been described as a kind of “social glue” that brings participants to share a common representation of the task (Roth & Roychoudhury, 1992; 1994). However, studies addressing collaborative concept mapping situations are still scarce. Many of them have focused on the study of interactions among knowledge mappers (Roth & Roychoudhury, 1992 ; Sizmur & Osborne, 1997; van Boxtel *et al.*, 2000). But we know very little about the effect of this activity upon learning and on task performance, whether it is compared to individual learning situations or to other collaborative learning activities. Moreover, results are contradictory. Hence, Okebukola & Jegede (1988) have shown that maps created collaboratively were of better quality than those produced individually and that participants in the collaborative group achieved better results on a post-test measuring higher levels of Bloom’s taxonomy of learning objectives. However, van Boxtel *et al.* (2000) did not find any significant difference in comprehension post-test scores with participants who produced a collaborative concept map, compared to those who produced a poster collaboratively. Participants involved in the Suthers & Hundhausen (2001) study who produced a specific type of concept map (an ''evidential map'') with the Belvedere tool did not outperform those who used a textual or matrix representation to analyze collaboratively various hypotheses of a problem. However, Osmundson *et al.* (1999) showed that written essays produced by 10-11 year olds after a three-week-long collaborative concept mapping activity were of better quality than those of students who had participated in other collaborative learning activities. Other researchers have assessed learning by using a post-test measure that consisted of asking participants to produce an individual map after the collaborative activity. Osmundson *et al.* (1999)

included such a measure. Scores associated to the individually-produced maps following a collective production were higher with participants involved in collaborative concept mapping. Stoyanova & Kommers (2002) obtained similar results with university students.

With the increasing popularity of telelearning and online learning in all educational circles and levels all over the planet, the remote, computerized collaborative construction of concept maps has also sparked researchers' interest over the last few years. Many researchers have focused on the interactions and processes which occur in such a context (Chiu, Wu, & Huang, 2000; Chung, O'Neil, & Herl, 1999; Fischer & Mandl, 2000, 2002; Reinhard, Hesse, Hron, & Picard, 1997; Suthers, Girardeau, & Hundhausen, 2002; van Boxtel & Veerman, 2001). Very few researchers have addressed the quality of the maps produced and the effects of such an activity on comprehension and learning. Moreover, all of these studies are limited to synchronous communication. Some studies highlight the low quality of collaborative maps while using a chat tool (Chung *et al.*, 1999). Slow typing (Chiu, Huang, & Chang, 2000), split-attention effect (Chung *et al.*, 1999) and lack of deictic affordances (Fischer & Mandl, 2000; Suthers *et al.,* 2002; 2003) could explain some of these issues. Most studies do not compare collaborative maps produced by live participants with those produced in remote interactions. Suthers *et al.* (2002; 2003) found no significant difference at a memory-for-factual-information post-test between participants who collaborated remotely to build an evidential map and those who worked face-to-face, although the participants in the face-to-face group wrote better essays. This paper presents a study where three situations of knowledge modeling[1] in dyads are compared, that is two remote scenarios (synchronous and asynchronous) and one face-to-face situation. This study investigates (1) collaborative knowledge modeling task performance, (2) individual learning as measured by a content-related test, and (3) the metacognitive interactions between members of dyads. This paper reports results related to the first two issues.

2 Methodology

2.1 Participants

Forty-eight adults (19 females, 29 males) of 19 to 57 years old (mean age: 34.6) participated in the study. Half of them were postsecondary full-time students in a variety of disciplines; others were workers with a postsecondary diploma and/or studying part-time at university. All were familiar with e-mail and most of them had already used chat software. Their self-declared prior knowledge in the targeted domain (cognitive information processing: CIP) and experience with knowledge modeling or concept mapping software were limited. Participants were randomly distributed into three groups: synchronous distance group (SYNCH; N=16), asynchronous distance group (ASYNCH; N=16) and face-to-face group (CONTROL group; N=16). They performed the collaborative knowledge modeling task in dyads (N=8 in each group). Pairing was assigned randomly and members of each dyad did not know each other before the experiment. Participants were paid to take part in this investigation.

2.2 Collaborative Knowledge Modeling Task

The collaborative knowledge modeling task consisted of co-elaborating a knowledge model in dyads immediately after having read individually, for 5 minutes, a short text (1 page) describing the principal components of a CIP system (sensory memory, short-term memory, long-term memory) and the CIP process as described in typical course material. Dyads had 50 minutes to construct their knowledge model using an object-typed knowledge modeling software called MOT developed at LICEF Research Center (Paquette, 2002).[2] In MOT, four types of knowledge objects are distinguished by using different graphic shapes: *concepts* (rectangles), *procedures* (ovals), *principles* (hexagons) and *facts* (rectangles with indented corners). These knowledge objects are linked to each other with arrows, the arrowhead indicating the link direction. Letter labeling is used to specify the link type: *Composition*, *Regulation*, *Specialization*, *Precedence*, *Input/Product (I/P)* and *Instantiation*. The software constrains the type of links that users can create between two specific types of knowledge objects. For example, a specialization link can only be used between two objects of the same type. Consequently, the specialization link is not accessible from the menu when the user is in the process of labeling

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1 A knowledge model is similar to a concept map as defined by Novak & Gowin (1984), except that, in a knowledge model, different types of knowledge objects (not just concepts) are represented with different shapes and a typology of predefined links is used.

2 MOT stands, in French, for "*Modélisation par Objets Typés* », which means « *Object-typed modeling* ». The LICEF Research Center, based at Télé-université in Quebec, Canada, is a laboratory dedicated to cognitive informatics and training environments. For further details on MOT, refer to the LICEF website: http://www.licef.teluq.uquebec.ca

a link between two different object types. However, users can put their own label on what is called an “untyped” link. A specific shape is also provided for “untyped” objects. It is also possible to link a “comment” to a knowledge object or a link. Some authors argue that a constrained approach to concept mapping adds more precision, exhaustiveness and coherence to the knowledge representation, thus facilitating its interpretation and communication (Gordon, 1996; Moody, 2000; Paquette, 2002; Reader & Hammond, 1994).

Partners of a dyad in the SYNCH group communicate with each other via the *NetMeeting* software. The screen was divided in two windows (see Figure 1). In the MOT window, partners of each dyad co-constructed their knowledge model. Only the one “with the hand” could work on it, the other acting as an observer. In the chat window, they could send messages to each other at any time during the session. The sent and received messages appear in different colors. Participants in the ASYNCH group used e-mail to send the co-constructed knowledge model to their partner. Thus, each member of the dyad could not see in real-time the work done by their distant partner. While waiting for the knowledge model from their partner (i.e. the one “with the hand”), participants were instructed to help their partner by sending him messages, to think about what to do next or to re-read the text. Dyads in the CONTROL group worked side by side at one computer. In all groups, one member of each dyad was identified randomly as the one “with the hand” at the beginning of the session. They were told that they could exchange the hand as often as they wished during the session.

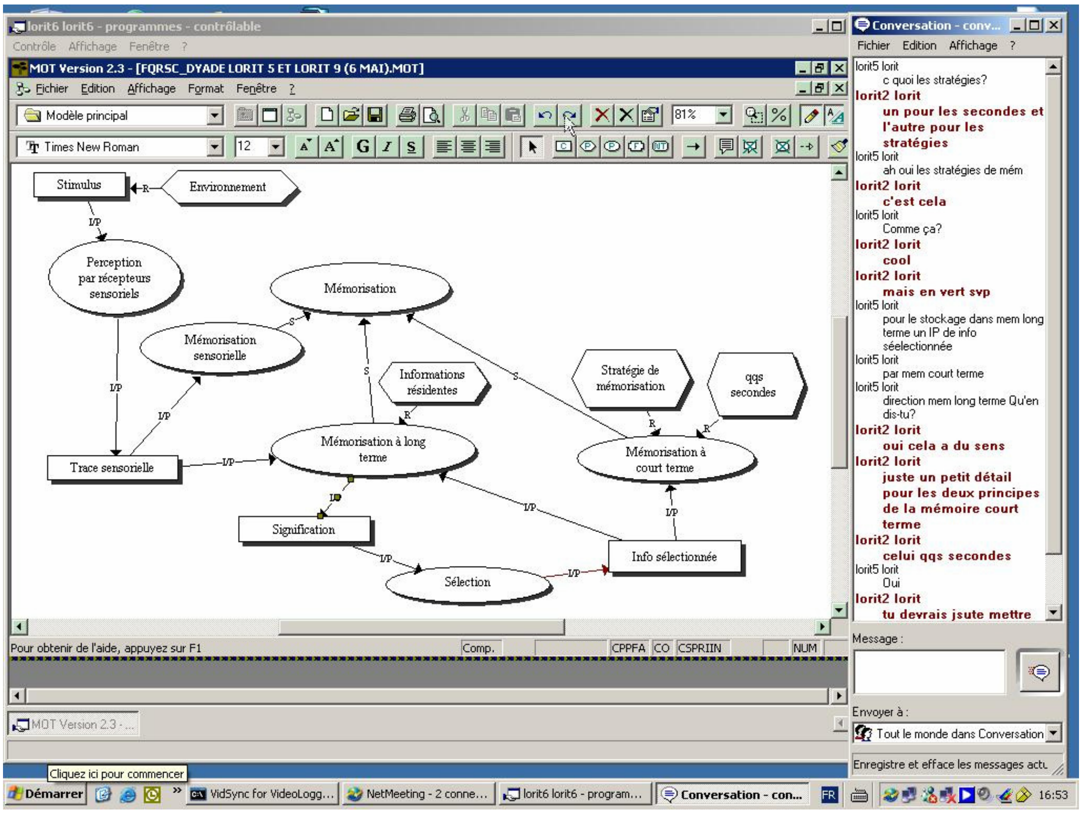

Figure 1. Screen capture of the NetMeeting window (SYNCH group)

2.3 Procedure

The experiment took place in 2003 at the LORIT, a distance learning engineering research laboratory based at Tele-universite, Canada.[3] To simulate distance in the experimental conditions, computer workstations were isolated from each other with partitions to ensure that participants could not see one another. Several sessions were organized, six students participating in each session (3 dyads). At the beginning of the session, participants were reminded about the research objectives and confidentiality issues. Second, a short pre-test (6 open-ended questions about CIP) was administered. Third, a 75-minute training session on the MOT software and on

3 For more information about the LORIT: http://www.licef.teluq.uquebec.ca/lorit/eng/index.htm.

knowledge modeling took place. During this training, participants did eight short exercises of increasing complexity (for example, identifying concepts, procedures and principles[4] in a sentence; linking those knowledge objects; reproducing a small MOT knowledge model in a text format, etc.). At the end of the training session, they were asked to represent individually a short text (6 lines) describing two waste-elimination methods in a knowledge model format using MOT. Twenty minutes was provided for this task. After a 15-minute break, participants performed the collaborative knowledge modeling task. Prior to this task, those in the experimental groups were briefly introduced to the online tool to use (chat or email). After a second break (20 minutes), participants filled out the post-test (identical to the pre-test).

2.4 Data Collection

The data collected during the experiment include the following: (1) pre- and post- measures of content-related knowledge; (2) the 8 exercises completed during the training session on MOT and on knowledge modeling; (3) individual knowledge models created after training on MOT, as a measure of knowledge modeling ability after training; (4) knowledge models created in dyads; (5) screen captures (with Windows Media Encoder) of the collaborative knowledge modeling sessions and (6) video capture of the collaborative knowledge modeling sessions (CONTROL group only). In this paper, we focus on pre- and post-test measures and on the evaluation of the individual and collaborative knowledge models produced.

2.5 Data Collection

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2.6 Data Analysis

Pre-tests and post-tests. Two independent coders scored the participants' answers to the 6 open-ended questions included in the tests. The maximum score was 21. Inter-rater agreement, as calculated with the Holsti's formulae (1969) on one-third of the total tests, was high (.89).

Knowledge models. Participants' knowledge models were compared to an "expert model" that was built by content experts and MOT experts[5] who performed the knowledge modeling task, first individually (same time limit constraints as the participants) and then collaboratively (without time limit[6]). Two scores were determined. The *Knowledge Objects score* (KO score) was calculated by summing up the total number of participant's knowledge objects that were also represented in the experts' knowledge model; for each knowledge object, 2 points were attributed if it was present and correctly typed and 1 point if it was present but incorrectly typed. The maximum score for the waste-elimination model was 30, and 82 for the CIP model. The *Propositions score* (P score) [7] was calculated by adding the total number of experts' knowledge propositions represented in the participant's knowledge model; for each proposition, 1 point was attributed if the same two knowledge objects were paired (regardless of the link); 1 point for each correctly typed knowledge object included in the proposition; 1 point if the link was correctly typed and 1 point for the correct link direction[8]. The maximum score for each proposition was 5. The maximum score was thus 72 for the waste-elimination model (18

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[4] Due to time constraints, participants were not introduced to the ''fact'' knowledge objects.

[5] For the waste-elimination model, participants were two MOT experts and one content expert. For the CIP model, participants were two MOT experts and two content experts (also knowledgeable in knowledge modeling). Experts were instructed not to use the "fact" objects.

[6] The experts were told that they had to come to a consensus in constructing a knowledge model, which took 25 minutes for the waste-elimination model and 64 minutes for the CIP model.

[7] Novak & Gowin (1984) defined a proposition as " two […] concept labels linked by words in a semantic unit" (p. 15).

[8] If the link was not correctly typed, we put 0 for direction because, in MOT, some types of link have a predefined direction (for example, a specialization link goes from the more specific knowledge object to the more general one). As some dyads in the ASYNCH group constructed more than one knowledge model, we also coded the knowledge objects and propositions that were individually introduced by each participant and added them to the dyad score.

propositions) and 260 for the CIP model (52 propositions). Two independent raters scored the knowledge models with this method. Inter-rater agreements, as calculated with the Holsti's formulae (1969) on one-third of the knowledge models, was very high (waste-elimination: .96 for KO score and .97 for P score; CIP: .95 for KO score and .98 for P score).

3 Results

Group equivalence for knowledge modeling ability. The total score attributed to the exercises completed by the participants during training does not differ significantly among groups, $F(2,47) = .190$, $p > .05$. Performance to the post-training individual knowledge modeling task is also equivalent for all groups on both measures: KO score, $F(2,47) = .035$, $p > .05$; P score, $F(2,47) = .642$, $p > .05$. Based on these results, we concluded that groups' knowledge-modeling ability was equivalent before the collaborative knowledge-modeling task. The mean score for the exercises is relatively high (mean = 42.08, SD = 10.39; participants' maximum score = 56/56), but performance at the post-training individual knowledge mapping task is low, especially for P score (mean = 22.48, SD = 12.08; participants' maximum score = 48/72); the mean KO score is 15.71, SD = 4.19; participants' maximum score = 23/30). Thus, participants were genuine novice knowledge modelers. Regarding the total score of the exercises, we found a positive correlation with the two scores of the individual knowledge-modeling task (KO score: $r = .477$, $p \leq .01$; P score: $r = .524$, $p \leq .01$). Those last two scores are not significantly correlated to the self-reported content knowledge (KO score: $r = .110$, $p > .05$; P score: $r = -.105$, $p > .05$).

Effect of modality of collaborative knowledge modeling on task performance. Table 1 shows descriptive statistics for the two performance scores of the collaborative knowledge modeling task. The ANOVA reveals an omnibus significant difference only on the KO score, $F(2,23) = 4.10$, $p \leq .05$. There are no between-group significant difference on the P score, $F(2,23) = .262$, $p > .05$). Post-hoc analyses (Tukey's HSD) reveal that the KO score is significantly higher for dyads in the CONTROL group than in the ASYNCH group ($p \leq .05$). If we consider the two sub-scores of the KO score (Number of KO and Type of KO), there is a significant difference only for the Type of KO variable, $F(2,23) = 4.13$, $p \leq .05$. Between-group difference for the total number of knowledge objects is not significant, $F(2,23) = 2.95$, $p > .05$.

	SYNCH (N = 8)		**ASYNCH** (N = 8)		**CONTROL** (N = 8)	
Scores	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Knowledge objects (KO) score	25.63	6.16	21.75	4.80	29.00	4.00
Number of KO	13.63	3.25	11.75	2.66	15.13	2.03
Type of KO	12.00	3.34	10.00	2.51	13.88	2.10
Propositions (P) score	26.50	10.04	26.00	12.76	30.25	15.21
Number of P	6.63	2.45	6.38	3.25	6.5	3.30
Type of paired KO	12.13	4.26	11.13	5.79	12.88	6.40
Type of link	4.75	2.71	5.50	2.83	5.88	2.75
Direction of link	3.00	2.14	5.13	2.30	5.00	3.16

Table 1: Descriptive statistics of collaborative knowledge modeling task performance scores

Effect of modality of collaborative knowledge modeling on learning. Not surprisingly, as showed in Table 2, content-related knowledge has been enhanced in all three groups after the collaborative knowledge-modeling task, although it remained relatively low. The ANOVA results indicate that the difference between post- and pre-test scores is not significant between groups, $F(2,47) = 2.84$, $p > .05$, although descriptive statistics shows that this difference is higher for the SYNCH group than for the other groups. This result is almost significant ($p = .069$).

	SYNCH (N = 16)		**ASYNCH** (N = 16)		**CONTROL** (N = 16)	
Scores	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Pre-test	3.56	3.16	3.81	1.60	5.31	3.00
Post-test	11.81	2.69	9.75	2.91	10.75	2.79
Difference between both tests	8.25	3.53	5.94	3.42	5.44	3.72

Table 2: Descriptive statistics for pre- and post tests scores and for difference between both tests

4 Discussion

In summary, our study shows (1) that performance at the collaborative knowledge modeling task is superior for dyads working at the same computer than for those who communicated asynchronously at a distance, but only in terms of the knowledge objects represented in the knowledge model (and more precisely in terms of specification of the type of the knowledge objects), not in terms of the propositions elaborated and (2) that groups do not differ on learning, although we found a tendency for remote partners who communicated synchronously to have learned more than participants in the two other groups.

The three conditions of this study can be distinguished in terms of "what is shared" in the interaction. In the face-to-face group and in the synchronous distance group, the knowledge construction *process* via a common workspace is shared. In the asynchronous distance group, only the *results* of the knowledge construction process are shared. The difference between the face-to-face group and the synchronous group lies in the speed and the facility of the sharing process, which are lower in the last group, probably due to slow typing (Chiu, Huang, & Chang, 2000), split-attention effect (Chung *et al.*, 1999) and lack of gestural deixis (Suthers *et al.*, 2002; 2003), three factors that could substantially affect the quantity and the nature of messages produced. Thus, the communication process was probably more fluent in the face-to-face condition. It is interesting to note that what seems to make a difference between groups on task performance is not the total number of knowledge objects nor the propositions represented in the models, but the specification of the type of the knowledge objects. Considering the low degree of familiarity of participants with content-knowledge and with MOT, and the complexity and short duration of the task, it is possible that participants of all dyads had enough time to identify a similar number of knowledge objects, but only those interacting in face-to-face had sufficient time to negotiate and reach consensus around the specification of the types of those objects.

No significant between-group differences were found for the Proposition score. It may be that the method used to evaluate the knowledge models underestimates the participants' capacity to elaborate valid propositions. For example, we observed that experts systematically represented all the inputs and outputs of each procedure represented in the two texts. Many participants put, instead, "precedence" links between the procedures. Although those propositions were valid (although less complete and less informative than the ones represented in the expert model), they were not considered as such in our coding scheme based on the comparison with an expert model. This could explain in part the very low performance on the Proposition score. Moreover, this method does not tell us much about participants' misconceptions in the target domain. We are currently elaborating another method based on cognitive semantics theories (Pudelko, Basque & Legros, 2003; Basque & Pudelko, 2003).

How can we interpret the lack of between-group difference on learning ? Some authors argue that sharing processes is more beneficial to learning than sharing only results. For example, Stoyanova & Kommers (2002) conclude from their study on the effect of three types of knowledge and resources sharing (shared, moderated and distributed) during a collaborative concept mapping activity on subsequent individual performance that "*learning effectiveness depends on the extent to which students share their learning, not only as results, but also as a process of knowledge acquisition and creation by a direct interaction*" (p. 131). Our results do not allow us to attest to this conclusion, as participants who seem to have learned the least (although this is only a tendency) are those who either shared the knowledge modeling process the most (CONTROL group) or the least (ASYNCH group). Results closely reflect Stoyanova & Kommers' conclusion for the ASYNCH group but not for the CONTROL group. It may be that if, as we hypothesized, partners working at the same computer spent more time negotiating about the type of the knowledge objects, they probably paid more attention to the MOT metalanguage than to the domain-related knowledge. However, we do not conclude that the use of the metalanguage is not beneficial to learning and text comprehension, as we think that the duration of the task was probably insufficient and the complexity of the task probably too high for novice knowledge modelers to allow participants to take advantage of this metalanguage. Another type of learning measures (for example, a written essay) could also lead to different results, as in the Suthers *et al.* studies (2002, 2003). Further research is needed to investigate the effects of using a metalanguage like the one in MOT on comprehension and learning. It seems necessary to analyze more in depth the process of collaborative knowledge modeling and the interactions between partners of dyads. This constitutes the next phase of our investigation, based on screen captures and video recordings of the collaborative knowledge modeling sessions.

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COLLABORATIVE KNOWLEDGE MODELING BETWEEN EXPERTS AND NOVICES: A STRATEGY TO SUPPORT TRANSFER OF EXPERTISE IN AN ORGANIZATION

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Abstract. We report a strategy of collaborative knowledge modeling between experts and novices implemented in a Canadian organization since 2002 to support the transfer of expertise and knowledge management in this organization. Participants use an object-typed knowledge modeling editor called MOT to elaborate knowledge models in pairs. A knowledge model is similar to a concept map, except that it is based on a typology of knowledge objects and on a typology of links, and its structure is not necessarily hierarchical. This technique is used to represent concepts, principles, procedures and facts related to a specific aspect of the work done by employees in the organization. The paper presents the rationale behind this project, describes how it is implemented and identifies some research issues.

1 Introduction

Over the last few years, economic and technological changes have brought major challenges to the business world. To remain competitive, businesses must rely upon the competence of their human resources. Indeed, business know-how is often intrinsically linked to the tacit knowledge acquired by employees while working for the organization. As almost all Western societies will soon experience substantial turnover of manpower (Advisory Council on Labour and Manpower, 2002; Treasury Board Secretariat, 2002), unless concrete efforts are deployed to save it, much knowledge will be lost. Indeed, much of the expert knowledge of an organization is implied and directly linked to the personnel; hence, it is lost once the employee leaves the organization (Lave & Wenger, 1991; Polanyi, 1966; Nonaka & Takeuchi, 1995). Jacob (2001) claims that depending on the realm of expertise, the implied knowledge of an organization can represent up to 70% of its competency assets. The issues revolving around the identification, the representation, the sharing, the validation, the re-use and the evolution of valuable knowledge are thus critical for organizations. Thus, many of them began to set up a knowledge management strategy supported by information and communication technologies.

According to Apostolou, *et al.* (2000), two approaches to knowledge management can be distinguished: (1) a product-oriented approach, which focuses on creating, storing and re-using documents. Such an approach aims to create an institutional memory; (2) a process-oriented approach, which focuses on the social communication process: "*in this approach, knowledge is tied to the person who developed it and is shared mainly through person-to-person contacts. The main purpose of Information Technology in this approach is to help people communicate knowledge, not to store it. This approach is also referred to as the 'personalisation' approach*" (p. 2). This approach aims to transfer expertise among people more directly.

The traditional strategy used to transfer expertise in organizations simply consists in matching less-experienced staff with more-experienced workers to allow the latter to share their know-how. However, this strategy is no longer suitable for our current challenges. Nowadays, people generally agree that transfer of expertise requires well structured activities anchored in real work situations. Some of these strategies recently developed in organization are job sharing between senior and newer staff members, buddy systems, mentoring, sponsorships, and communities of practice (McDermott, 2001; Wenger, 1998).

From an individual standpoint, knowing how to transfer one's own knowledge remains challenging. Knowledge-transfer aptitudes and pedagogical competencies are not innate. Moreover, those who excel in the field are not necessarily aware of the manner in which they perform their work. Tacit knowledge is difficult to externalize. Most of the time, experts use their knowledge ''live'' and rarely have the opportunity to consciously reflect upon what they are doing. Basically, they cannot verbalize what they know, nor can they explain their "action model" (Bourassa, Serre, & Ross, 1999). Transferring one's expertise thus requires that the experts delve deeper into their knowledge. It also requires that the experts spell out what seems clear to them, although that is not the case for other people. Many studies have shown that experts have difficulties formulating concrete and detailed explanations of a task even if they are aware that their explanations are intended for novices (Hinds, Patterson, & Pfeffer, 2001). Cognitive psychology research conducted in the mental model approach indicates that expertise consists of a highly organized structure of different types of knowledge stored in long-term memory. As this mental model is activated by a task, in a given context, in an economical fashion (much knowledge is encapsulated in automatic procedures), it is difficult to express it into words (Chi, Glaser, & Farr, 1988; Ehrlich, Tardieu, & Cavazza, 1993; Gentner & Stevens, 1983; Johnson-Laird, 1983). The lack of means available to deal with these cognitive and metacognitive difficulties creates somewhat of a bottleneck for organizations which aspire to address expertise transfer (Barjou 1995).

A possible solution to address the transfer of expertise consists in creating situations where experts have to explicitly provide their mental model of their field in an external representation. Research has shown the dynamic and contextual nature of such a strategy (Gentner & Stevens, 1983; Johnson-Laird, 1983). This requires the integration of two processes: verbal interactions in the context of professional activity and some means to trigger the externalization of the expert's knowledge according to the novice's needs and knowledge level. The co-construction of concept maps shows some interesting potential in the field. Many studies conducted in educational settings show that creating concept maps is beneficial to learning (Holley & Dansereau, 1984a; Horton et al., 1993; Novak & Gowin, 1984). Creating external representations such as concept maps gets people deeply involved in knowledge processing of a given field and forces them to reflect on the knowledge they already possess or the knowledge they are in the process of creating (Jonassen, *et al.*, 1997). Pair-building concept maps by an expert-novice team has the potential to favor intersubjectivity and establish a common ground for knowledge construction (Rogoff, 1990; Lave & Wenger, 1991), to provide instances of cognitive and socio-cognitive conflicts and triggers conflict-solving processes (Doise & Mugny, 1991; Hinde, Perret-Clermont & Stevenson-Hinde, 1988) as well as to support the use of scaffolding strategies by experts (Bruner, 1987). It has also been suggested that collaborative knowledge modeling prompts subjective discussions about the experience within a structured framework (Ballay, 2002).

This paper presents a collaborative knowledge modeling strategy by dyads of experts and novices that has been ongoing for two years in an organization of 20 000 employees, where over 60% of the staff will be retiring before 2014 (Charlebois, 2002). This strategy is similar to those used in the studies of Coffey and his colleagues (Coffey & Hoffman, 2003; Coffey, Hoffman, Cañas, & Ford, 2002) and of Cañas, Leake, & Wilson (1999). However, it differs in the fact that knowledge modeling is jointly conducted by experts and novices (not solely by experts) and that it is a knowledge management strategy that is primarily process-oriented. Our hypothesis is that collaborative knowledge modeling by expert-novice teams is particularly helpful in addressing the cognitive and metacognitive difficulties related to transfer of expertise in a professional setting.

2 Description of the Project

The collaborative knowledge modeling strategy was first used in 2002 at Hydro-Québec, the main producer, provider and distributor of electricity in the province of Quebec, in Canada. Up to now, over 150 experts and 150 novices from various departments (management, electrical engineering, civil engineering, etc.) have participated in this pilot project.

Instrumentation. MOT[1], a knowledge-modeling editor developed by Paquette (2002) from the LICEF Research Center[2] is used in this project. The knowledge modeling technique suggested by Paquette is somewhere between the formal techniques used in Artificial Intelligence (AI) and concept mapping techniques developed by Novak & Gowin (1984). Indeed, on one hand, the knowledge models produced with Paquette's technique are supported by a more structured representation language than the one used in concept maps, but less structured as those used in AI. The modeling language suggested by Paquette distinguishes graphically four types of knowledge (*concepts*, *procedures*, *principles* and *facts*), based on a typology used by Merrill (1994) and by Romizowski (1981) in the field of instructional design. Paquette also proposes a typology of six types of links (*is composed of; is a sort of; precedes; is an input/product of; regulates; is an instantiation of*). Although some researchers working with the concept mapping or the networking approaches also use some predefined labels for links (Chung, O'Neil, & Herl, 1999; Chiu, Huang, & Chang, 2000; Holley & Dansereau, 1984b; Osmundson, Chung, Herl, & Klein, 1999), the represented knowledge is generally treated as a single type of knowledge object (concepts). According to Paquette, specifying the type of knowledge objects and the type of links adds more precision and coherence to knowledge representations, thus facilitating their interpretation and communication. On the other hand, the structure of a MOT knowledge model is not strictly hierarchical, as it is

[1] MOT is an acronym for *"Modélisation par Objets Typés"*, which means *"Object-typed modeling"*. The French term "*mot*" also means "*word*".
[2] The LICEF Research Center is a laboratory that is dedicated to cognitive informatics and training environments (www.licef.teluq.uquebec.ca).

in concept maps. With MOT, it is also possible to illustrate networks, tree diagrams, causal diagrams, flowcharts, etc., as well as models which combine different types of structures. In fact, the choice of the structure is left to the knowledge modeler. Among other functionalities of MOT, we find the possibilities of creating a sub-model of each knowledge object represented in the first-level model (also called principal knowledge object) and of linking documents of different formats (with OLE links) to each knowledge object included in a model.

Figure 1 illustrates an example of the principal knowledge model produced by an expert-novice dyad working in the field of civil engineering. This example shows the procedure “Devise an urban station project”, which is regulated (R-link), at Hydro-Quebec, by some specific actors named “Designers”. The main input (I/P-link) of this procedure is a document labeled “Pre-Project” and its main product (I/P-link) is “Construction plans and estimates”. The procedure is composed (C-link) of seven sub-procedures, some of which precede others (P-link). Finally, the dyad indicated that this procedure is regulated (R-link) by some organization standards for urban station projects.

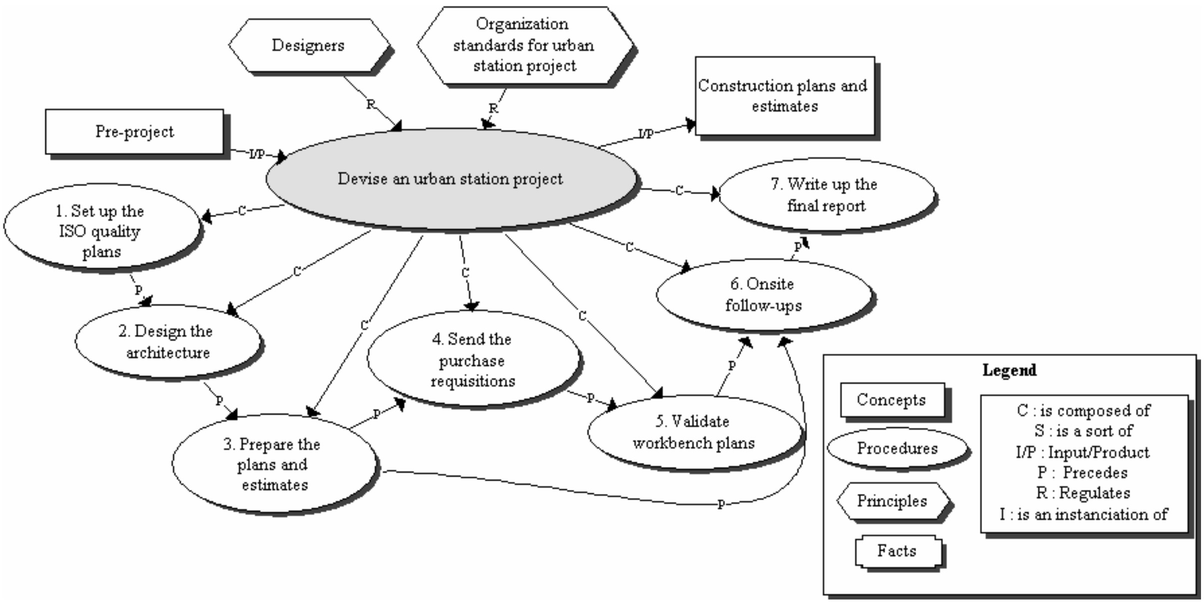

Figure 1. Example of a first level model produced by an expert-novice dyad at Hydro-Quebec.

Procedure. The procedure used to implement the expert-novice knowledge modeling strategy in the organization includes many steps. First, the selection of the expertise to model stems from the head managers’ priorities. Heads of sectors select the “knowledge modeling project”: for each of them, they identify the main goal of the project, the type of expertise to model, the novice and the expert involved, the potential end-users and the resources required. Once the teams are set up, members of each team delimit more precisely the domain of their modeling activity. Most of the time, it consists in a challenge faced by the novice when performing a specific task (for example, conducting a compliant wastewater treatment, producing a preliminary study for a given project, approving or inspecting equipment, etc.) or some other procedures that have not yet been documented.

A two-day knowledge modeling training session is then provided on-site to groups of 8 to 10 people. In the first half-day, an instructor introduces participants to the knowledge modeling technique with MOT. Then, over the next day and a half, under the supervision of the instructor, each team starts to co-model the knowledge associated to the challenge problem previously selected. After these two days, each team continues to develop its own model. The group meets again two weeks later to present the models of each team: all participants and the instructor can then suggest modifications and ways to complete the models. Depending on the complexity of the expertise represented and the ease each team shows with the technique, up to five additional workdays can be required to produce a model that could be considered an appropriate reference tool for the actors who will subsequently apply the expertise represented. Up to now, more than 80 % of the knowledge models have been completed by participants. Interestingly, some participants spontaneously used OLE links to join some job aids already in use in the organization to their knowledge model. Finally, the teams present their respective final models to managers and colleagues of their work sector.

3 Preliminary Observations

Collected data are still scarce. We recorded on video one training session and screen-captured (with *Windows Media Encoder*) the collaborative knowledge modeling session of three of the five dyads participating in this session, but we just began an in-depth data analysis. Thus, we will present only a few of the spontaneous commentaries shared by participants during this recorded training session. As the second author of this paper is the coordinator of the pilot project at Hydro-Quebec and the last one is the MOT training session instructor, we also report other anecdotal data based on their own interaction with participants and on one informal focus group session conducted by the coordinator of the pilot project. We will also first describe how the knowledge models produced by dyads have been used up to now in the organization.

Uses of the knowledge models. Knowledge models produced by the expert-novice teams have been downloaded in a computerized knowledge management system (*LiveLink*): they can then be consulted, reused, adapted, updated, commented, etc., in order to share the expertise on a larger scale within the organization[3]. Thus, although the collaborative knowledge modeling strategy has been defined primarily as a process-oriented approach to knowledge management, it is also compatible with a product-oriented approach. About 20% of the novice participants have begun to use the models as live reference documents. Some competency development specialists have also begun to use them for training purposes. However, the usage of the knowledge models is still limited. A planned and systematic adoption strategy such as the one proposed by Rogers (1983) remains to be implemented. Hydro-Québec is currently drafting a corporate program to deploy this strategy, rendering it available to all of the members of the organization, starting in January 2005. As the use of this type of graphical representation of tacit expert knowledge seems to represent a major innovation for employees, it will probably take some time for them to discover how to integrate them efficiently in their own activities: the knowledge models have to become a genuine *instrument* for their own activities (Vérillon & Rabardel, 1995).

Attitudes of the participants. In general, the knowledge modeling strategy was considered positive by both the experts and the novices. However, we found a certain number of nonpartisans, especially among the experts who seemed to lack time to participate in these activities due to their heavy workload. Most found the software very user-friendly, although some had difficulties with the process of categorizing knowledge. Many commented that the strategy helped them to organize their own knowledge. Some experts lamented that collaborative knowledge modeling with novices slowed down their own modeling process; however, for others, the interaction with novices was essential to externalize what seemed obvious for them and MOT helped them capture a very large body of their knowledge in an economical fashion. Others recognized the inherent advantages of graphical representations while adding that they remained more comfortable sharing their knowledge by spelling it out in a written text or through live demonstrations. On the other hand, novices appreciated having a reference document that will prevent them from constantly referring to the expert: “By using the model, I will be able to do my job without asking lots of questions to the expert”, commented one of the participants. The instructor noted that the dyads interactions seemed to permit to each employee to become more aware of the complexity of the others’ duties and of the similarities of some tacit knowledge used in many tasks.

4 Discussion

The collaborative knowledge modeling strategy experimented at Hydro-Quebec seems promising for expertise transfer within the organization. However, it brings up many research questions. A survey of the literature (Basque & Pudelko, in press) allows us to identify, among others, a series of factors which are likely to influence its efficiency. These issues must be addressed.

First, there are a series of *factors which are related to the individuals involved*. We can wonder, for example, how individual variables, such as the experts’ level of motivation to share their knowledge, the individual’s spatial or verbal skills or their cognitive style affect the efficiency of such an activity. The few studies that investigated these topics were conducted in school settings (Obekula & Jegede, 1988; Stensvold & Wilson, 1990; Reed & Oughton, 1998; Oughton & Reed, 1999; 2000). It would be valuable to conduct such research with adult participants in their professional setting. For example, Stensvold & Wilson (1990) have shown, in a study conducted with Grade 9 participants, that creating concept maps was more beneficial to the students with low verbal skills than to those with high verbal skills. We may thus hypothesize that concept maps

[3] All of the graphics of a MOT model can be converted into XML (Extensible Mark-up Language), thus facilitating such an activity.

aimed to represent knowledge would be particularly effective for certain types of employees (for example, manual workers).

Second, there are some *factors which are linked to the organization of the co-modeling situations*. For example:

- *The active contribution of each participant involved in the activity*: A setting where the participants are involved in the creation process together (as is the case in this project) would be more effective than a situation where only the results of the activity are shared (Stoyanova & Kommers, 2002).
- *The level of asymmetry of the partners' expertise paired up for the activity*: A gap that is too severe could be detrimental. According to various studies conducted in adult-children dyads, asymmetric relations tend to trigger relational regulation, rather than sociocognitive regulation of the conflicts. Hence, for the interaction to be effective, problem-solving activities must be conducted on a sociocognitive level, and not on a social level (Doise & Mugny, 1981; Perret-Clermont & Brossard, 1988). Moreover, once aware of this asymmetry, the participants' representations of the relationship constitute a factor which can affect their partnership. Hence, participants with low self-esteem will tend to overestimate the competency of their partners, thus influencing their interactions.
- *The knowledge modeling training method*: Research conducted in the field of concept mapping provides little indication as to the most efficient method to train people for this type of activity. To what extent, and how, should people involved in collaborative knowledge modeling in a professional setting be trained to a knowledge modeling language in order to minimize the cognitive load of such an activity (Chang, Sung, & Chen, 2002)? Moreover, how can we guarantee sufficient freedom of expression to allow the representation of different knowledge structure to suits the needs of the knowledge modelers? How can we help them to make links among knowledge in the most significant and useful manner, an activity considered very difficult by many researchers (Basque & Pudelko, 2003; Cañas *et al.,* 2003; Faletti & Fisher, 1996; Fisher, 1990; Novak & Gowin, 1984; Roth & Roychoudhury, 1992)? Are there any aspects of collaboration that should be the target of specific training? These questions should be investigated further.
- *The representation language and the representation tool used:* Once again, a series of questions deserve to be explored further. For example, is the representation system suggested by the tool appropriate for all fields and sectors? Does it allow the representation of a variety of knowledge structures that can be organized into temporal script, in causal diagrams, etc? Is it best to impose the use of knowledge and link typologies? If strategic knowledge is at the heart of expertise, can we say that expertise is mostly represented in the "principles" included in a model?

Third, there are *factors related to the global organizational environment*. Among those, we find, for example, the level of competition (between individuals or between various groups) that exists within the organization, the level of hierarchy present in the organization, the feelings of confidence and safety that employees have towards the organization, the manner in which knowledge is shared within the organization, the existence of incentives associated with expertise transfer (tokens of recognition, rewards, release time), etc.

Aside from investigating these different factors, it would be relevant to evaluate the effects of collaborative knowledge modeling on the expertise transfer and the productivity of the organization. We believe that these effects cannot be investigated without also analyzing the knowledge construction processes instigated by the experts and novices during collaborative knowledge modeling. As mentioned earlier, we have initiated an exploratory research study on the topic.. We hope to identify the various types of mediations that occur during the activity, using the instrumental approach, based on Vygotsky's (1978) sociocultural theory and developed by Rabardel (1995; 1999) among others.

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TEACHING BY DOING WITH CONCEPT MAPS: INTEGRATING PLONE AND CMAPTOOLS

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Abstract. Learning technologies are increasingly used as a fundamental component of all teaching and learning activities. A mix of methodological frameworks and sophisticated technological instruments is now the standard toolbox of many teachers. In this context, we propose a model of *teaching by doing*, to be used within university courses or professional workshops, which fully integrates in a teaching continuum, the (traditionally distinct) moments of presentation of theoretical concepts and moments of practical demonstration of the topic to be taught. In this model we extend the Ausubel concept maps-based advance organizer in the form of an interactive advance organizer, where concept maps are fully integrated with the application to be taught. We then present an application of this model to a course on the Plone Content Management System, where we developed an integration of Plone with CmapTools for preparing interactive teaching materials and organizing the educational activities. The results demonstrate the effectiveness of this approach, especially in terms of responsiveness, manifestation of interest and willingness to learn on the part of the participants.

1 Introduction

Plone (www.plone.org) is an Open Source Content Management System (CMS) and has quickly become one of the biggest and most successful projects in the history of open and free software, already rich in success stories: Linux, Apache, OpenOfficie.org, the GIMP. At the beginning of 2004, it passed the 100.000 download mark from the plone.org servers. It builds on the well-proven design of Zope (www.zope.org), an object-oriented web application development system. Its ever increasing diffusion makes it a sort of de facto standard for Open Source CMS, to be used inside or outside organizations, both as intranet content server and as Internet collaborative portals. This trend induces increasing needs for training and self-training on this new platform. In 2000, LIASES started to design, develop and deliver (although using traditional tools and methods) different courses on many ICT topics, with a special focus on Zope and Plone.

In our research project, we depart from this approach and base our teaching methodology on concept maps fully integrated with the topic we have to teach: Plone. From Joseph D. Novak: "Concept maps are tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts or propositions, indicated by a connecting line between two concepts". The concept map interface used for our Plone course was constructed using CmapTools, the *knowledge modeling kit* developed by the Institute for Human and Machine Cognition (cmap.ihmc.us).

Concept maps were born out of the constructivist theory of learning, which holds that the learner constructs or builds his/her own knowledge, as opposed to the previous notion of knowledge as something that was acquired through direct transfer from books or experts. In the constructivist theory of learning, information can be acquired, but knowledge is pieced together only through the incorporation of new information or ideas into the framework of the learner's existing knowledge (Cheek, 1992).

Concept maps are used to structure argument forms and express relationships between ideas (Gaines & Shaw, 1993). In education, the use of concept maps has been promoted to investigate a student's understanding of a topic (Novak & Gowin, 1984). The novelty of the concept map-based interface for first-time users raises the question of whether training is required to use concept maps and related representations effectively. The proponents of knowledge maps have suggested that effective processing of knowledge maps requires training in map reading and construction (McCagg & Dansereau, 1991).

The goal of this research project is to integrate special learning technologies (some based on concept maps) into a unique teaching environment aimed to support educational activities. This environment in turn allows another level of integration among (1) presentation of theoretical concepts and (2) practical presentations, for example lessons and exercises or, more generally, theory and practice. From this twofold integration, we propose a model of *teaching by doing*. We then present an application of this model to a course on Plone, where we developed an integration of CmapTools with Plone itself for preparing interactive teaching materials and organizing the educational activities.

The paper is structured as follows: section 2 presents Plone in more detail and section 3 presents the fundaments of concept maps. In section 4 we present the *teaching by doing* model and focus on the integration of different aspects of the teaching process. In section 5 the specific application of this model to a course on Plone is presented, where CmapTools and Plone are integrated. Section 6 concludes the paper and proposes some future directions of research.

2 Plone

From the official presentation of Plone: "Plone is an out-of-the box ready content management system that is built on the powerful and free Zope Application server. It requires minimal effort to set up, is deeply flexible, and provides you with a system for managing web content that is ideal for project groups, communities and intranets". It may be used for building traditional web sites, collaborative portals, intranets, document publishing systems and represents a powerful platform for implementing e-learning platforms (Margarita, 2003) or Learning Management Systems.

It is one of the most powerful Open Source CMS, thanks to its strong commitment to quality, usability and accessibility. Plone is:

- easy to install. Different click-and-run installers exist, which allow a quick installation of a full-blown CMS in a few minutes
- multi-platform. It runs on many platforms, including Linux, BSD, Solaris, Windows and Mac OS X
- international. The interface has been translated into more than 30 languages, and tools exist for managing multilingual content
- standard. Plone follows standards for usability and accessibility (it is compliant with US Section 508 and with the W3C's WAI AA rating) and web standards like XHTML and CSS
- easy to use. Both user and manager interface are web-based and very friendly. Content managers can add, update, and maintain content through the web
- extensible. Plone can be scripted using web standard tools and Open Source languages and may be extended by creating new content types or service tools.

In our application, we make wide use of the Plone web orientation in integrating it with concept maps, generated in their web form by CmapTools (Cañas, Carvajal, Carff & Hill, 2004).

Plone has some very powerful features like:

- full manageability of users. Through a fine-grained mechanism of roles and permissions, administrators can restrict users to limited zones of the site or to access only specific services and tools
- real-time indexing and cataloging of contents. A built-in search engine allows searches to be carried out in the site, depending on the rights possessed on the different objects
- publication workflow. Each content type may have a separate publication workflow, which defines the different actors, actions and states of the publication process
- cataloguing of documents with metadata. Plone follows the specifications of the Dublin Core Metadata Initiative (www.dublincore.org).

Figure 1 shows the Plone first level concept map we use in the Plone course (see section 5).

3 Concept maps

Conceptual maps are artefacts for organizing and representing knowledge. Their origin lies in David Ausubel's theories about the psychology of learning of the 1960s. Their objective is to represent relations between concepts in the form of propositions. Concepts are included within boxes or circles, whereas the relations between them are explicated by means of lines connecting their respective boxes. The lines, in turn, have associated words describing the nature of the relation that links the concepts (Dürsteler, 2004).

In this context, Joseph D. Novak defines a concept as "a perceived regularity in events or objects, or records of events or objects, designated by a label". The label of a concept is usually a word. Propositions are "statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected with other words to form a meaningful statement. They are also called semantic units, or units of meaning". Concepts are correlated by relations, boxes and linking lines. Conceptual maps are structured in a hierarchical way, where the most general concepts lie at the root of the tree and, and as we descend the structure, we find the more specific ones. Doesn't this sound familiar? Indeed, like many other things conceptual maps can be represented, where the nodes are concepts and the arcs the relations between them.

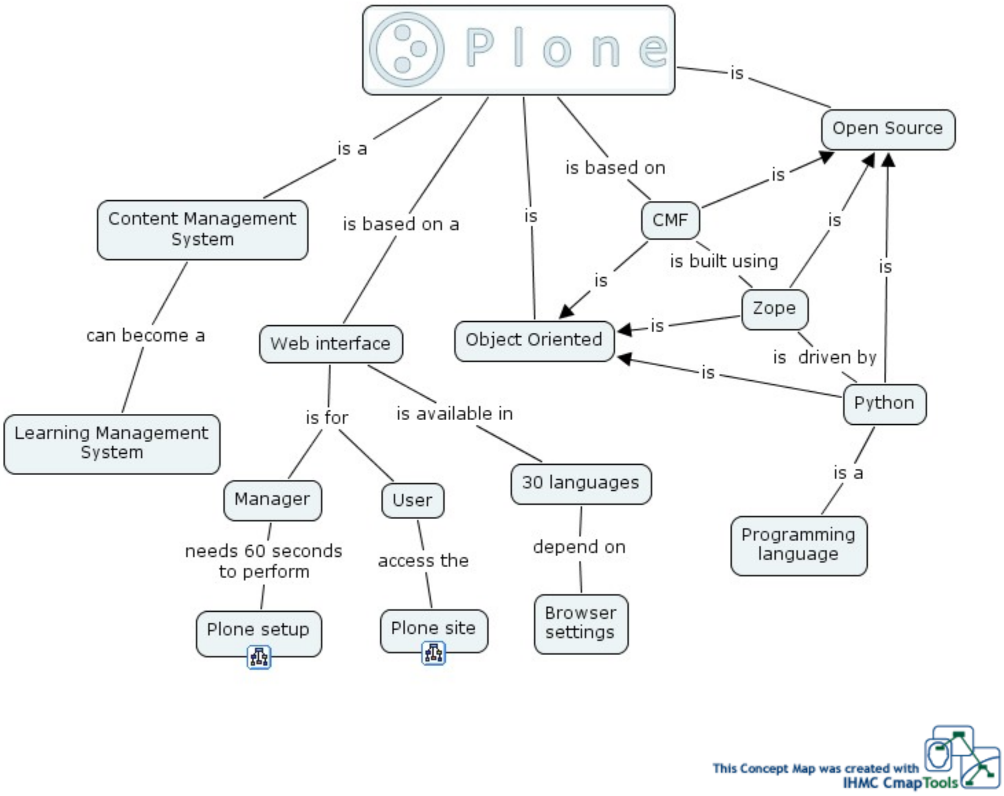

Figure 1. The Plone first level concept map.

Concept maps have several useful applications: they can be adopted in education, in government and business, in industry and the military (Cañas et al., 2003). They provide a new method for organizing and browsing through information and may be an effective navigational tool for hypermedia environments (Cañas, Ford & Coffey, 1994). Because of their graphical nature, concept maps may make desired information more accessible.

In particular, Ausubel (Ausubel, 1968; Ausubel, Novak, & Hanesian, 1978) advocated the use of "advance organizers" to foster meaningful learning. A concept map can be utilized as an advance organizer (Novak & Gowin, 1984; Novak, 1998; Willerman & Mac Harg, 1991). Advance organizer Concept Maps might be constructed by teachers or other experts. The Concept Map advance organizers can then be used in various ways as part of the classroom experience. They might be presented at the beginning of a textbook chapter or other instructional unit, or used as a guide for a lecture that is presented in a class. They might be used to present an overview of multimedia, with links to instructional materials associated with different topics.

A Learning Environment Organizer (LEO) was developed to support computer-mediated courses and provide the learner with a graphical advance organizer (Coffey & Cañas, 2003). It is used to build graphical course representations for computer-mediated instruction. LEO is used to create organizers which represent the topics in a course, their sequence in terms of prerequisite relationships, additional explanatory information about the relationships among them, and links to pertinent instructional resources. This approach is effective and useful both for teachers in organizing knowledge objects and for learners in browsing a self-chosen set of topics in a non-linear fashion.

In the same directions of research followed by LEO, we propose a new approach which overcomes the traditional educational approach, in which theory and practice are separated, and gives life to a *continuum temporalis* based on a *teaching by doing* model.

4 Teaching by doing

A mix of methodological frameworks and sophisticated technological instruments is now the standard toolbox of many teachers. In this context, we propose a model of *teaching by doing*, which fully integrates in a *teaching continuum*, the (traditionally distinct) moments of presentation of theoretical concepts and moments of practical demonstration of the topic to be taught. In this model we extend the concept maps-based advance organizer (Ausubel, 1968; Ausubel, Novak & Hanesian, 1978) in the form of an *interactive advance organizer* (IAO), where concept maps are fully integrated with the application to be taught. Assimilation theory, formulated by these authors, explains how concepts might be acquired and organized within a learner's cognitive structure in a meaningful manner through different strategies. Advance organizers play an important role in the initial and progressive differentiation of learned concepts. If construction of knowledge begins with our observation and recognition of events and objects through concepts we already possess, and if we learn by constructing a network of concepts and adding to them, concept maps-based advance organizers play a fundamental role in the meaningful learning of a given domain of knowledge. Our approach integrates the two aspects that the traditional didactic approach splits: theory and practice, thoughts and actions.

From a teacher's point of view, IAO allows him/her to prepare and organize traditional materials for the course (slides, texts, images) and browse through them using the concept map. But IAO also allows the teacher to integrate interactive sessions of use of the program into the map. For each node of the map, that is for each Plone concept, a resource may be created which opens a real-time session giving access to a zone of the Plone environment, corresponding to the specific topic. In this way, the teacher can browse freely in the Plone site to present related concepts and features. At the end of the practical presentation, browsing of concepts begins again through the concept map.

From a learner's point of view, IAO provides an environment which fosters qualified learning and integrative thinking, avoiding the usual swapping syndrome where students stop to study theory to do exercises and vice versa. Merging these two moments gives a more immediate perception of the knowledge model and the skills to acquire.

Classical didactics treats knowledge as a river in which the teacher drives his students. We rather prefer to imagine knowledge as a sea where the teacher explores one direction and can suggest other possible paths, by using the underlying concept map. The Plone course where we experimented this model unfolds in two separate moments:

- in the morning, the teacher used the IAO environment to develop the main theme and to show how to use the most important features of Plone;
- in the afternoon, the students individually used the IAO environment as a compass to explore the other routes, to deepen the different concepts and to extend their knowledge to the minor aspects of Plone.

Thanks to integration we have an environment (Figure 2) which promotes meaningful learning and where knowledge can grow: the teacher explains how to use Plone using CmapTools, and at the same time, Plone integration helps the teacher to guarantee a sort of continuum between concepts and practice. The students can immediately experiment what they are studying, without the need to leave their books, move to check if they had got the focus of the arguments and then go back. By using IAO (in this case CmapTools and Plone together), they move freely from one topic to another, with a continuous insight into the theoretical and practical aspects of every topic.

5 The case of the Plone course

We validated this model in a Plone course we organized recently as part of a two-week workshop which brought together fifteen trainers, managers and Information Technology (IT) specialists from different countries to examine and discuss the latest developments in Learning Technology Standards and Learning Management Systems and their impact on the process of designing, developing and managing instructional media and learning environments.

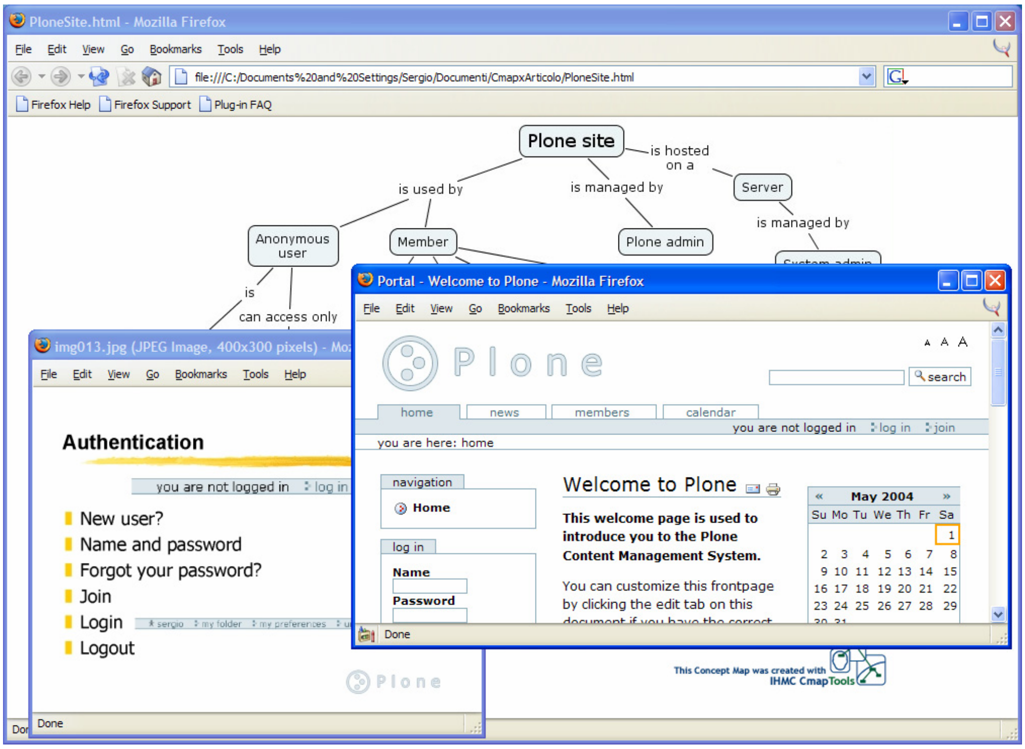

Figure 2. The teaching environment (the concept map, a slide and the Plone site are visible).

As to course organization, a preliminary introduction to reading concept maps is proposed to the participants, followed by a presentation and collective reading of the main (first level) concept map. This first step serves both as a short tutorial on concept maps and as a gentle introduction to general Plone topics. Subsequently, the IAO tool is constantly used as a browsing tool during teacher presentation and proved to be effective

As to preparation of materials:

- we build concept maps and sub-maps based on the level of deepening we defined for the different course topics
- for the sake of usability and easiness, we define an almost fixed set of four resources associated to each node of the maps:
  1. Slide. The object drawn from traditional presentation containing the information
  2. Inside Plone. The link to the page of the Plone site related to the concept
  3. Link. A link to an external resource (site or specific page) for deepening the topic, mainly a page of the documentation section of the www.plone.org main site
  4. Document. A local document (in PDF format)
- we prepare, and give to the participants at the end of the course, a CD-ROM version of the web maps and associated resources, allowing them to explore by themselves offline and individually deepen the knowledge model and related information.

During the classroom sessions, the teacher is helped by the IAO tool to adapt the presentation to interaction and questions coming from the learners. With respect to sequential presentation tools, the teachers have at their disposal a direct access presentation tool allowing them to jump instantaneously to the live session or to the static content to use for answering the question.

More generally, we avoid typical drawbacks of sequential presentations:

- loss of information about structure of the underlying knowledge model
- difficulties teachers encounter to present the relations among concepts

- difficulties attendants encounter in fully understanding the logical flow of the presentation and the non-linear organization of the presented topics.

After the classroom sessions, students can activate a self-learning process, based on the materials they receive. They can use these materials as-is, renouncing the live sessions but accessing all the other resources, or install on their own personal computer the full package (Plone in our case) and recreate the very same environment the teacher used during the classroom sessions. Students can benefit from this kind of self-learning by searching for other concept maps that may be relevant to the one they are building, and by looking for additional material that could help them enhance these maps.

After some sessions, we observed that some students reached a good level of knowledge on Plone and were able to manage the main concepts. So we suggested that they improve and complete the teacher's Plone maps by incorporating in the maps the information and concepts that were presented as associated resources (mainly slides and links to the Plone site). Although this assignment was "paper-based" (they worked only on a printed version and on the web version of the concept maps, so they cannot directly modify them), we noticed the emergence of spontaneous collaborative learning where the cleverest participants helped the others and where everyone contributed to the map building process with their own knowledge of the different topics.

This framework is also at the heart of the constructivist approach to teaching and learning, which treats learning as "meaning making". The use of such maps serves as a primer for active learning in which students organize their prior knowledge to deal with the present context, and prepare to modify or add concepts and relationships. As a starting point for analyzing a topic, this tool is useful for brainstorming, to spark discussion, and for the teacher to observe and correct existing misconceptions. The learning environment provided by starting a topic in this fashion also conveys to the student that there are alternate frameworks for representing and dealing with knowledge.

The feedback from participants at the end of the course is very positive: they very much appreciated having the possibility to use the same tool (IAO) that the teacher also used; thanks to concept maps, they were able to share their ideas, their problems and solutions. They said that the *teaching by doing* model is effective and successful: during the course, they first become the actors of their learning and after the classroom sessions they can consolidate the knowledge they progressively acquired.

Until now, having to deal with short courses, we did not experiment true forms of cooperative learning neither in traditional form nor based on concept map collaborative building (with the exception of paper-based collaboration). In the future, for longer courses, we want to foster cooperative uses of concept maps and use the CmapServer (Cañas et al., 1993). We are going to focus our attention on students: learning diagrams are central to encouraging students to construct their own worldviews or "mental models" and reflect upon relationships and systems structure. Because students have experiential knowledge about the environment, it is important to use their frameworks as a starting point of learning, using their existing experiential knowledge to acquire the "mental model" as the starting point. This model must lead to the framing of the specific problem in the context of the relevant environmental system.

6 Summary

In this research project, we have proposed a *teaching by doing* model, by performing a two-level integration (1) at a methodological level, between theoretical and practical presentations, and (2) at a technical level, between concept maps-based presentation and interactive use of specific software platforms. This model is based on a tool, *Interactive Advance Organizer* (IAO) that we built and used for fully integrating Plone and CmapTools. We have then shown a successful example of deployment during an instructional course.

The results demonstrate the effectiveness of this approach, especially in terms of responsiveness, manifestation of interest and willingness to learn on the part of the participants. A side effect is the high availability and usability of the post-course material distributed to the students. Trough this experience, teacher and students became actors in a meaningful learning and integrative thinking process that, in the future, will be integrated with concept maps-based collaborative learning activities.

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LOS MAPAS CONCEPTUALES EN EL CONTEXTO DE LAS REDES SOCIALES: *UN NUEVO ESCENARIO DE APLICACIÓN*

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Resumen: Este trabajo es una exploración preeliminar de la relación que puede existir entre la forma en que los niños y niñas relacionan conceptos e influyen la construcción del conocimiento grupal y las relaciones sociales que ellos establecen en el momento de producir colectivamente trabajos o actividades. Creemos que es posible esta relación porque ambos procesos implican una estructura de redes dónde nodos y ligas tienen una jerarquía y porque, en ambas se genera conocimiento a través de la aplicación de estrategias de relación. Para comparar ambas redes se utilizó la herramienta de los mapas conceptuales y los sociogramas. Para los primeros utilizamos la herramienta tecnológica Cmaptools y para los segundos UCINet.
Se diseño un experimento con dos grupos de sexto grado de primaria para comparar la estructura cognitiva representada en un mapa conceptual grupal, y la estructura de las redes sociales de ese grupo, al identificarse procesos comunes en su capacidad para establecer relaciones.
En este trabajo se plantea un posible marco conceptual y se propone una metodología de evaluación y valoración de mapas conceptuales como redes. Tanto la metodología de evaluación y valoración de redes de conceptos como las mediciones utilizadas en los sociogramas requieren profundización y validación mediante otros experimentos, sin embargo los resultados obtenidos son muy alentadores. Si se llega a encontrar evidencia contundente de esta asociación y de la validez de la metodología propuesta, estaríamos contribuyendo con una importante herramienta para el diagnóstico y planificación de relaciones grupales.

1 Introducción

Los mapas conceptuales ofrecen la posibilidad de representar el conocimiento en forma de nodos (conceptos) y vínculos (relación entre los conceptos). De forma equivalente, los sociogramas permiten representar relaciones sociales como redes, donde las personas constituyen nodos y los vínculos representan relaciones. La existencia de herramientas computadorizadas ha facilitado un uso creciente de mapas conceptuales y de sociogramas. El uso común de gráficos en forma de red invita a pensar si las técnicas utilizadas para analizar redes, pueden aportar ideas para el análisis de mapas conceptuales. Así mismo el uso de mapas conceptuales puede contribuir a explicar el por qué de ciertas dinámicas sociales.

Una forma de abordar esta posible relación es en el contexto de la producción intelectual grupal. Estudiar cómo la estructura social se refleja en la construcción grupal de conocimiento y/o cómo el resultado de un mapa conceptual grupal puede ofrecer un Proxy o pistas de cómo es la estructura social del grupo que lo produjo.

Explorar esta relación en cualquiera de las dos vías representa varios retos de distintos niveles de complejidad metodológica y puede tener distintas aplicaciones. En nuestro caso nos interesa saber si los mapas conceptuales construidos en forma grupal pueden reflejar la estructura social. En el contexto escolar esto tendría valor pues si bien el análisis de redes sociales es muy riguroso, la obtención de información para establecer mediciones es siempre difícil, tiene mucha probabilidad de introducir sesgos. Además, en el contexto escolar puede ser contraproducente el análisis tradicional de redes sociales si se hace periódicamente, mediante el uso de métodos tradicionales, mientras que, por el contrario, la representación y producción periódica de conocimiento mediante mapas es natural y además deseable.

Este paper reporta el resultado premiliminar de un experimento diseñado como una primera aproximación metodológica y buscando resultados que si bien no pueden ser definitivos, puedan servir para justificar y motivar trabajo de investigación adicional. Durante el proceso de preparación de este documento no se encontró referencias a ningún experimento similar en la literatura sobre redes sociales y tampoco en la referente a mapas conceptuales.

1.1 Antecedentes

Entre los muchos usos posibles de la construcción de mapas conceptuales, uno de ellos es la elaboración de mapas colectivos o grupales. Los mapas conceptuales inicialmente planteados por Joseph Novak han evolucionado como una poderosa herramienta para la facilitación y generación de experiencias de *aprendizaje colaborativo* (Cañas, 2003). El ejercicio de construirlos es en sí mismo una técnica de facilitación que nos ha resultado muy exitosa en distintos contextos. Hemos visto y experimentado este uso en muy diversos grupos sociales y comunidades, desde el análisis de problemas de evasión aduanera y tributaria (Barahona, 2001), hasta talleres con profesores universitarios (INCAE, 2000). Desde ejercicios de planificación estratégica (Hernández, 2003) hasta ejercicios con grupos de campesinos y estudiantes. Su uso agrega valor en ambientes lúdicos como el preescolar del Instituto Educativo Moderno y ambientes muy serios para la facilitación de actividades formales de resolución alternativa de conflictos (CEMEDCO, 2004).

Además de la experiencia de los investigadores en la producción de mapas grupales, es importante informar que los estudiantes que participaron en nuestro experimento, están muy familiarizados con el uso y producción de mapas conceptuales como parte del trabajo ordinario en su escuela.

1.2 Consideraciones conceptuales

El fundamento teórico de los mapas conceptuales (Novak, 1988), es que la estructura cognitiva está organizada jerárquicamente a través de redes de proposiciones. Novak y Gowin (1988) definen los mapas conceptuales como "recursos esquemáticos para representar un conjunto de significados conceptuales incluidos en una estructura de proposiciones". Según Novak, basándose en la teoría de aprendizaje significativo de Asubel (1978), las proposiciones se estructuran formando una ***jerarquía de inclusión***. En el ejercicio de la construcción de un mapa conceptual, el sujeto va estableciendo tipos de relación. El tipo de enlace explica el tipo de significancia de la relación, y el lugar en que se ubica el concepto en la red de relaciones, define el tipo de relación: derivativa, correlativa, supraordinaria o combinatoria. Además los enlaces pueden ser, directos, recíprocos, generar enlaces cruzados, contribuyendo con el "grado"de significancia de la relación. Existen conceptos relevantes de los cuales se desprenden gran cantidad de enlaces, y conceptos a los cuales llegan gran cantidad de enlaces desde otro concepto, también los hay como conectores entre diversas partes del mapa.

La Teoría de Redes aporta instrumental conceptual, matemático y estadístico para el análisis y representación de interacciones sociales. Según M.Newman (2004), "una red es un conjunto de ítems, los cuales llamaremos *vértices*, o algunas veces, *nodos,* con conexiones entre ellos que se llaman ligas. Los sistemas que asumen la forma de redes (llamados grafos en la literatura matemática), e inundan el mundo.(Internet, redes sociales, redes metabólicas.)"

El análisis de redes sociales puede centrarse en el individuo (egocéntricas) o en grupos (sociocéntricas o completas). Las medidas más comunes para analizar la red de un individuo se refieren a distintas implementaciones de las ideas de centralidad, cercanía y grado de intermediación. En la medición de grupos, las más frecuentes son densidad y cohesión. También se puede signar valores a las ligas: intensidad, capacidad informativa, el flujo de información que pasa a través de la liga, distancia entre los nodos, presencia de aglomeraciones, de nodos aislados, frecuencia de interacción, etc.

Un mapa conceptual puede ofrecer información redundante, circular o innovadora, cualidades que también caracterizan a las redes sociales desde la perspectiva de la calidad de la información que circula dentro de la red social. Existen vías, canales, caminos a través de las cuales fluye la secuencia de información en ambos escenarios y estas ideas también son consideradas en la escala propuesta para medir mapas conceptuales y también en el análisis de las redes sociales de nuestro experimento.

2 Metodología y análisis

Se busca establecer si los mapas conceptuales de dos grupos son diferentes, si sus redes sociales son significativamente diferentes y si la comparación sugiere que puede existir algún tipo de relación entre los mapas de cada grupo y su estructura social.

2.1 Población estudiada

Se eligieron los dos grupos de sexto grado de la educación general básica, de una escuela privada en Costa Rica, (Instituto Educativo Moderno, IEM). La tabla 1 ofrece algunas estadísticas descriptivas de ambos grupos.

Grupo	Nivel socio-económico (Moda)	Nivel educativo de los padres (Moda)	Rendimiento académico promedio	Grado de inteligencia emocional (según escala desarrollada para tal efecto)	Edad promedio (en años)	Distribución por género	
						M	H
A	Medio-alto	nivel universitario	82	74.44	11.8	3	13
B	Medio-alto	nivel universitario	85	74.17	11.3	4	16

Tabla 1: Comparación de las características socio-demográficas de los dos grupos de estudiantes.

2.2 Puesta en marcha de la experiencia

En la primera semana de clase del presente curso lectivo, se le pidió a los niños y niñas que en subgrupos (2 o 3 estudiantes), escogidos voluntariamente entre ellos, se dieran a la tarea de realizar un mapa conceptual individual sobre la pregunta ¿qué es liderazgo? utilizando como software el CmapTools. Una semana después se les convocó para realizar, cada grupo, un **mapa conceptual grupal** utilizando la misma pregunta. El proceso fue facilitado por dos de los psicólogos de la institución.

Una vez concluido el mapa, se les invitó a asegurarse de que los conceptos y las relaciones entre los conceptos que habían establecido en el trabajo en subgrupos, estuviera representado en el mapa grupal.

En otra sesión se aplicó **un sociograma** a efectos de determinar la estructura de redes sociales que existe en cada grupo. Las categorías de asignación fueron: cada estudiante debía citar a los tres compañeros que consideraran más amigos, a los tres más influyentes, y a los tres que más aportaban. Además debía escoger para las mismas categorías a tres estudiantes del otro salón de clases (si es que así lo encontraban).

A efectos de realizar una confirmación de la comprensión de los conceptos a utilizar en el sociograma, se procedió a realizar una experiencia de validación, a través de una nueva clasificación de sus compañeros, esta vez, citando cualidades de cada uno de ellos. Los datos se tabularon y se conformó una tabla con categorías de cualidades para cada estudiante, según la percepción de sus compañeros.

No existen mapas conceptuales “malos” ya que representan el proceso de construcción del conocimiento actual de un individuo o grupo. Sin embargo, en un intento por generar posibilidades de comparación entre mapas, se han realizado interesantes esfuerzos como los del grupo Knowledge Manager Hypersoft, y los de María Aracelly Ruiz-Primo (2000), entre otros. Para esta investigación, se diseñó una escala que permitiera la comparación entre dos mapas conceptuales a efectos de llevar a cabo la experiencia.

Para evaluar la calidad jerárquica de los mapas conceptuales se diseñó un cuadro conceptual comparativo para los mapas, apoyándose en categorías de evaluación del análisis de redes. A partir de ese cuadro se diseñó la escala de evaluación para los mapas conceptuales. La asignación de puntaje es subjetiva, con base en la experiencia y alguna de la literatura revisada, sin embargo, es uno de los elementos que necesitan ser revisados y establecidos de forma más rigurosa. La tabla número 2 presenta la escala propuesta.

Ideas principales en la evaluación de redes sociales	Ideas semejantes en evaluación de mapas conceptuales	Valor propuesto para escala de medición
Centralidad: es un atributo de los nodos que resulta de su posición estructural. Los actores con más vínculos tienen más oportunidades porque tienen más opciones. Es una medida de la contribución de esa posición a la importancia, poder o influencia de un actor en la red. Existen varios enfoques o implementaciones del concepto de centralidad. ***Centralidad de grados*** el número de ligas que tiene un nodo **Centralidad de grafos de Freeman** describe la centralidad de la población como un todo. Expresa el grado de desigualdad o variación en la red como un porcentaje de todas las conexiones posibles	Generación de varios enlaces a partir de una proposición. Estructuras generales no específicas Para su calificación revisar el tipo de relación que genera: derivativas (ejemplos) correlativas(explicativas)	1 2
Centralidad de Cercanía Es la distancia más corta en que la información puede llegar a más nodos, medida como la suma de la distancia geodésica de cada actor al resto. El que está más cerca de los demás nodos de la red está en una posición más favorable.	Presencia de relaciones de inclusividad (presencia de conceptos específicos a partir de conceptos generales) Conceptos que generan nuevos enlaces. Cada nivel de la jerarquía	5
Grado de eigenvector (Bonacich)*:* busca encontrar los actores más centrales, considerando la estructura como un todo. Nos dice que para estar cerca, un par de actores deben tener distancias cortas entre ellos en ambas direcciones. Un actor que está conectado a muchos actores que están a su vez bien conectados, tiene una medida más alta *(diferente a un actor que está conectado a muchos actores aislados).* La centralidad de un nodo es proporcional a la suma de las centralidades de los nodos a los cuales está ligado.	Diversidad de enlaces a partir de un solo concepto. Salen varias proposiciones de un concepto) ampliación (supraordinario): combinatorias Direccionalidad de la relación	3 4 10
Centralidad de Grado de Intermediación (Betweenness*)*: Es la frecuencia con que un nodo aparece en el camino más corto que conecta otros dos nodos. Son los agujeros estructurales	Conecta redes de conceptos con otras redes de conceptos Presencia de relaciones no jerárquicas: denominadas relaciones cruzadas	10

Tabla 2: Resumen de comparación teórica y criterios de evaluación para redes y mapas conceptuales

2.3 Análisis de los mapas conceptuales

Se presentan a continuación el mapa conceptual construido por cada grupo de estudiantes, su calificación cuantitativa y un análisis cualitativo.

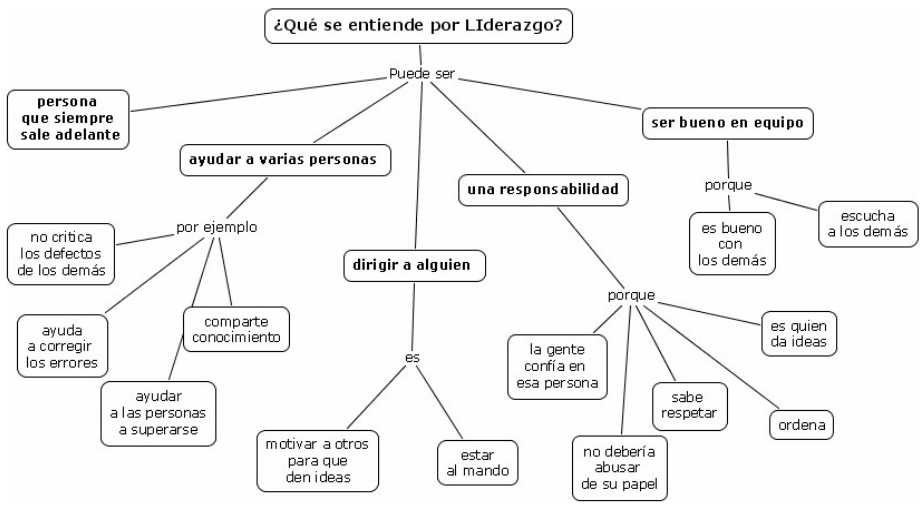

Figura 1: Mapa conceptual Grupal Sexto A

Figura 2: Mapa conceptual grupal Sexto B

Criterios de evaluación	**Valor de cada categoría**	**Puntos Obtenidos**	
		Grupo A	**Grupo B**
¿Han sido incluidos los conceptos importantes en el mapa?	10	10	10
Proposiciones derivativas (ejemplos, ilustraciones)	1	4	2
Proposiciones correlativas(explicativas)	2	6	14
Cada nivel de la jerarquía	5	10	20
Enlaces de ampliación	3	0	9
Enlaces de síntesis	4	0	12
Cada relación cruzada	10	0	20
Direccionalidad de la relación	10	5	10
TOTAL		35	96

Tabla 3: Evaluación del mapa conceptual de sexto A

El mapa presenta muchos de los conceptos relevantes del tema, (según el mapa ideal de un grupo de expertos) por lo que se le asignan 10 puntos. La estructura conceptual en términos de enlaces es de organización conceptual "baja" ya que son solamente cuatro enlaces y explican la relación en términos de ejemplos y explicaciones de poca profundidad de abstracción. (se evidencian 4 proposiciones de ejemplos y 3 explicativas). Sólo ofrece un segundo nivel jerárquico .No ofrece relaciones cruzadas, ni de relación jerárquica entre diferentes proposiciones.

En términos de la capacidad para hacer relaciones, no se reflejan en la producción grupal habilidades para hacer conexiones significativas entre diversas redes conceptuales. ***Podría predecirse un grupo conformado por ciertos líderes que son quienes toman las decisiones de su red, pero con poco grado de cercanía entre otros nodos centrales. La información de la red es redundante y con poca capacidad para integración de la diversidad***

El mapa del grupo B presenta el manejo de muchos conceptos relevantes, por lo que se le asigna el puntaje 10. Presenta una proposición derivativa y 7 correlativas. Refleja capacidad de organización de la información alta ya que se evidencian 4 niveles jerárquicos. Además establece tres proposiciones de ampliación (es, cuando, porque implica). Genera proposiciones de profundidad conceptual importante en la que se establecen condiciones explicativas, de causalidad, de importante especificidad. Presenta además dos relaciones cruzadas entre redes de conceptos. Con claridad se perciben varios "clusters" conceptuales y aunque no hay indicación de direccionalidad a través de las flechas, sí puede seguirse la secuencialidad en la profundidad de la información. *de sus conceptos, manteniendo hasta la particularidad del tipo de letra con que se realizaron*

Desde el punto de vista de las redes sociales se puede anticipar que el grupo presenta importantes nodos o líderes que establecen conexiones entre ellos, y que tienen la capacidad para integrar los puntos de vista de otros, lo que sugiere intercambio y apertura en el manejo de la información.

Es importante destacar, que el mapa de este grupo que también fue construido con el aporte particular de sub-grupos.

3 Análisis de las redes sociales

Para analizar las redes sociales utilizamos un cuestionario, que nos permitió recoger información sobre sus relaciones de amistad, colaboración reconocida e influencia reconocida dentro de cada uno de sus grupos de sexto grado. Por la naturaleza de este experimento utilizamos solamente la información sobre *influencia* para construir los siguientes sociogramas. Será un trabajo posterior analizar las relaciones de los mapas con esas otras categorías.

Ideas principales en la evaluación de redes sociales	a		b	
Centralidad de grados el número de ligas que tiene un nodo. Por la naturaleza de la pregunta se trató el gráfico en forma asimétrica (para considerar la dirección) y se presenta la medida de In-degree	MF 12 AO 12 EB 09	X=2..9 S= 3.9	MJ 9 CG 9 JC 8	X=2.8 S= 3.1
Casos con InDegree menor que 2:	12/20=.59		7/17=.41	
Centralidad de grafos de Freeman	50.42%		41.41%	
Centralidad de Cercanía (Distancias Geodésicas de Freeman) Es la distancia más corta en que la información puede llegar a más nodos, medida como la suma de la distancia geodésica de cada actor al resto. El que está más cerca de los demás nodos de la red está en una posición más favorable.	MF 76 AO 73 EB 70		CG 73 MJ 73 JC 67	
Grado de eigenvector (Bonacich)*:* La centralidad de un nodo es proporcional a la suma de las centralidades de los nodos a los cuales está ligado.	MF .42 AO .38 EB .34 PC .33		MJ .416 CG .412 JC .370	
Centralidad de Grado de Intermediación (Betweenness*)*: Es la frecuencia con que un nodo aparece en el camino más corto que conecta otros dos nodos.	MF 22.90 AO 21.4 AC 15 EB 10.93 PC 10.53		MJ 35.17 CG 31.17 JC 24.83	
Densidad	.15		.17	
Cohesión (basada en distancia)	.337		.254	

En ambos grupos aparecen con consistencia tres figuras que son centrales y que se reconocen influencia entre si. En general, las medidas básicas de estas dos redes parecen reflejar una cierta equivalencia estructural, que también puede verse en la siguiente figura.

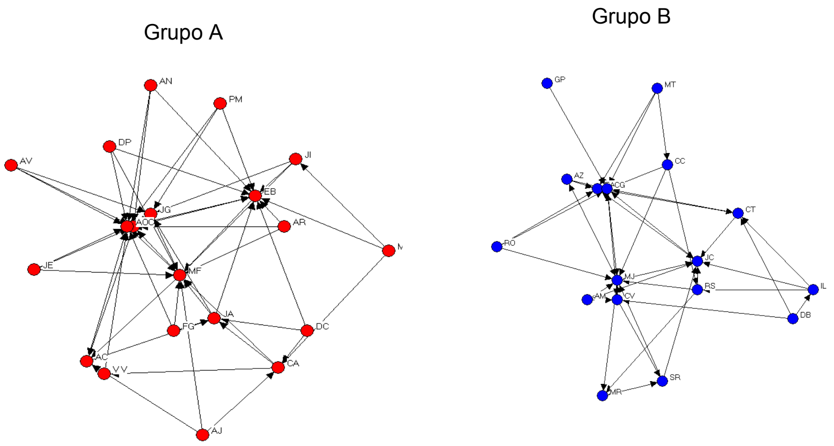

Figura 4: Estructura de redes (Influencia)

Sin embargo, a pesar de la similaridad en la centralidad promedio para ambos grupos, la variabilidad parece alta en ambos con respecto a su promedio, es más alta para el grupo A. Lo que sugirió explorar la distribución de centralidad para el resto de miembros del grupo, encontrándose un diferencia aparentemente significativa en la cantidad de miembros del grupo a las que se les concede poco o ningún grado de influencia entre el grupo (número de in negrees menores a 2).

Para ilustrar este punto se graficó de nuevo la red facilitando la apreciación gráfica de este fenómeno. La figura 5 muestra una estructura social similar a la que podrían estar prediciendo los mapas conceptuales. El grupo A y el B cuentan con tres figuras centrales que se reconocen influencia entre si, sin embargo el B cuenta con la posibilidad de reconocer la influencia de más miembros y los miembros más influyentes tienden a considerar otros fuera de su círculo de miembros centrales como influyentes, lo que podría estar asociado a la diferencia apuntada en la producción de mapas grupales, entre otras cosas porque ello permite que la información que circula sea menos redundante y con mayor capacidad para intercambiar experiencias.

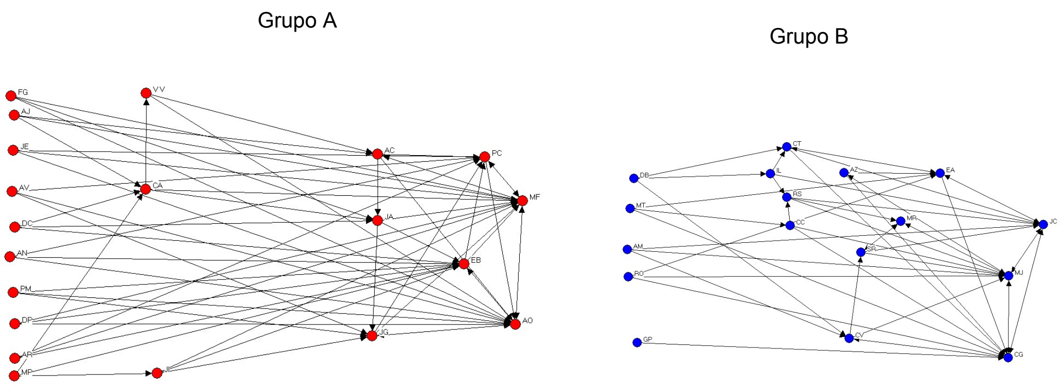

Figura 5: Estructura de redes (Influencia)

4 Discusión

La pregunta que orientó a la presente investigación, señalaba que a partir de la similitud conceptual entre *mapas y redes*, la capacidad de un grupo para relacionar conceptos se podía ver reflejada en la conformación de las redes sociales de ese grupo.

Los dos grupos de estudiantes, sexto A y sexto B, con condiciones similares en términos de rendimiento académico, promedio de edad, habilidades sociales (escala de inteligencia emocional), conformación familiar (nivel educativo y nivel socioeconómico) fueron sometidos a la misma experiencia de trabajo, el mismo día y por la facilitación de las mismas personas.

Sin embargo, los resultados obtenidos al realizar grupalmente los mapas conceptuales sobre el tema de *liderazgo,* los productos resultaron diferentes en cuanto a cantidad de conceptos, niveles jerárquicos de las relaciones, tipos de proposiciones y profundidad del conocimiento expresado.

Esa diferencia, **también parece reflejarse en la forma de organización social al interior de cada grupo,** al aplicarle algunos de los indicadores del análisis de redes. Así el grupo con menor capacidad para generar relaciones entre conceptos, es el que presenta una red de interacción caracterizada por una especie de menor transitividad, en la que la interacción se concentra en “subredes”, (los nodos con mayor centralidad presentan interacciones hacia dentro, generándose poca intermediación) y donde los niveles de cercanía limitan la capacidad de interconexión. Se caracteriza por un grupo que al limitarse en interconexiones, se limita también en el ejercicio de su diversidad.

El grupo que evidencia mayor capacidad para relacionar conceptos, presenta una conformación social de mayor interconexión porque los nodos con mayores grados de centralidad realizan ligas con otros nodos igualmente altos. La presencia de nodos conectores evidencia relaciones entre centralidad e intermediación, lo que facilita que las “subredes” estén interconectadas. Así, su estructura es más dispersa y hay mayor número de agujeros estructurales.

Una vez calificados los mapas conceptuales y comparados los datos estadísticos del análisis de redes, los resultados parecen orientarse en la dirección de la hipótesis de trabajo: *los modelos mentales,como las habilidades para relacionar conceptos y construir conocimiento, representada en un mapa conceptual grupal, pareciera verse reflejada en la dinámica de la organización social de ese grupo.*

Si bien se trata de una primera experiencia de investigación, cuya propuesta metodológica debe aplicarse a varios grupos más, a efectos de proponer generalizaciones, estos resultados abren un interesante espacio de aplicación para la herramienta de los mapas conceptuales: el ámbito de las relaciones interpersonales, el dominio de lo social y sobre todo sugieren que podría establecerse alguna forma de aproximación a la estructura social a partir de la producción colectiva de un mapa conceptual.

5 Reconocimientos

Esta investigación contó con el apoyo de un importante equipo de trabajo, todos miembros del Instituto Educativo Moderno: **Gabriela Villalobos, Ocampo, Sandra Beirute, Marcela Amador(www.iemonline.org).**

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EXPANDING CONCEPT MAPPING TO ADDRESS SPATIO-TEMPORAL DIMENSIONALITY

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Abstract. Concept mapping has been used in multiple research domains for a variety of purposes such as brainstorming, knowledge elicitation, student testing and evaluation. Our work has applied the technique with pilots, emergency managers, emergency responders, and image analysts. Indeed, concept mapping has proven to be valuable both as an end state to represent and in turn understand knowledge, as well as the means to acquire knowledge from experts or users. This paper explores one path in the history of concept mapping use as a knowledge elicitation device, emphasizing its application in frameworks of knowledge acquisition. We conclude with proposed perturbations that help researchers account for spatio-temporal factors in task and event elicitation.

1 Introduction

Concept mapping has emerged from varied backgrounds and influences (e.g., cognitive science, learning and instruction) while being put to use for multiple purposes (e.g., brainstorming tool, knowledge elicitation, student testing and evaluation). Indeed, concept mapping has proven to be valuable both as an end state to represent and in turn understand knowledge, as well as the means to acquire knowledge from experts or users. Our own use of concept mapping (historical and current) derives from the AKADAM (Advanced Knowledge And Design Acquisition Techniques, McNeese et al., 1990; Zaff, Snyder, & McNeese, 1993); AKADAM was devised for user-centered knowledge elicitation in support of participatory design (McNeese et al. 1995). AKADAM utilized scenario-building, concept mapping, IDEF functional decomposition, and design storyboarding techniques as an integrated bundle to promote synthesis of reconfigurable prototypes and technology that emphasis cognition acting in context. Over the last 15 years, we have adapted AKADAM techniques (e.g., concept mapping used with storyboarding and video-taping) to respond to various demands inherent in work situations. An example of this is that we started working more consistently with teams and in turn developed CM as an active group technique for eliciting and representing models of how groups formulated and used knowledge in a given context (McNeese et al., 1992). From this initial conceptualization of concept mapping within the AKADAM framework, several complementary strains also developed and matured. Our particular research (distilled from AKADAM) has focused on the mutual interplay of understanding, modeling, and measuring individual / team cognition within complex systems. This can be achieved when several representations and uses are exploited through integrated methods and tools. Specifically, the application of *cognitive engineering techniques* (McNeese et al. 1995; McNeese 2002), *cognitive field research tools* (Sanderson et al. 1994; McNeese et al. 1999), *cognitive modeling methods* (Perusich & McNeese 1997; Perusich, McNeese, & Rentsch, 1999), *scaled world simulations* (McNeese et al. 1999; McNeese, 2003), and *team schema similarity measurement* (Rentsch et al. 1998; McNeese & Rentsch 2001) have all played together as a coherent nexus of research activity. Our latest comprehensive view – the Living Lab Approach (McNeese, in press) – actively utilizes four major components (field research, knowledge elicitation, scaled world simulations, and reconfigurable prototype designs) to develop theory, knowledge, models, and interventions of use. The Living Lab facilitates the latest use of concept mapping with the intention to connect concept maps within this larger perspective of integrated research. Earlier techniques in concept mapping (McNeese, Zaff, & Snyder, 1993) primarily reflected access of declarative and (to a certain extent) and procedural memory. Our current work in concept mapping is designed to reflect processes more attuned to situation cognition (e.g., reflecting episodic and eidetic memories, temporal patterns and conflict, and the invariants that constrain action in contexts). In turn, the paper looks at historical markers in AKADAM but puts forth some of our new directions in temporal-based concept mapping.

The objective of this paper is to review use of concept mapping in the AKADAM framework from past to current uses; and to suggest some new perturbations based on what has been discovered over the past 15 years. The goal is to establish some new directions and adaptations given previous use of the techniques. Certainly, AKADAM represents only a limited view of the grand terrain of concept mapping. Other authors and schools of thought provide both similar (e.g., Klein, et al., 1993; Gaines & Shaw, 1992; Gordon, Scmierer, & Gill, 1993; Hoffman, Crandall, & Shadbolt, 1998) and different ideas and cases on how concept mapping provides value and use. One more point – as we scale the terrain of concept mapping – the particular lens that allows us to see the wide angle of what we are doing is that of cognitive systems engineering and design (e.g. Hollnagel & Woods, 1983; Rasmussen et al, 1994; Sanderson, McNeese, & Zaff, 1998; Woods, 1998).

2 Basic Foundations

Much of our approach that lies behind concept mapping is tied to agent-environment transactions wherein cognition and context are both considered valuable components of *experience*, mutually influencing each other (see Young and McNeese, 1995). The approach we have utilized emphasizes both cognition and context. In turn, the theoretical foundation for our work lies within what other authors have referred to as situated cognition (Brown, Duguid, & Collins, 1989), distributed cognition (Hutchins, 1995), plans and situated actions (Suchman, 1987), socially shared cognition (Resnick, 1991). This is best captured by the statement, "What is inside your head is a reflection of what your head is inside of" (adapted from Mace, 1977). This provides justification for both the mental models (Johnson-Laird, 1983) that encode experience for future use and expectations, the prominent role of perception in experience, as well as the ecological context that offers affordances and effectivities for an agent. This is not unlike other approaches that Rasmussen, Flach, Klein, Woods, and Vicente (see Eggleston, 2003) have elucidated within the general purview of cognitive systems engineering. All of these approaches give credence to the role of context and environment and even social environment – but some give the role of context a greater emphasis therein invoking a greater ecological emphasis.

In our early work (McNeese et al. 1990) the intent was to use the concept map (1) as a means to facilitate user-centered, participatory knowledge elicitation that would allow users to spontaneously access knowledge and capture that knowledge visually as concepts, what we then referred to as *knowledge as concepts* (2) to include within the knowledge capture and representation of the behavioral-shaping constraints (Rasmussen, Petjersen, & Goodstein, 1994) that the context brought strongly within situations (3) to translate the captured knowledge into designs or tools (McNeese et al. 1995), termed *knowledge as design.* In summary, our approach is based on capturing specific cognition in context using concept mapping procedures and then representing an external mental model as variant forms of concept maps (e.g., definitional, procedural, fuzzy).

3 Procedures Related to First Principles

The basic foundation of our CM procedures was predicated on two theoretical first principles: *spontaneous access of knowledge* (Bransford & Stein, 1993) and *ecological contextualism* (Hoffman & Nead, 1983). The first principle focused on the cognitive processes inherent in having a user heed or explain "the things" that influenced their behavior (for a given problem or domain of interest). When people spontaneously access their knowledge (without being told to do so), it is an indication that knowledge has been integrated and put to use for specific situations and, in turn, is salient in their memory. To bring this idea out as part of our procedures, we would begin with an expert (or group of experts) being asked to develop a choice scenario. The scenario would be contingent on recalling their own experiences (stories, critical incidents, routines, memorable occasions) with potential focus on a specific problem that the expert encountered in their own work. This scenario then provides a basic-level timeline which can be used later on in more temporal aspects of the procedure. After they have worked together on the scenario (we prefer this if we have more than one expert working at a given session as it gives an initial cross-validation), they begin to develop (with the concept mapper) a *concept definition map*. In older terminology, a definition map would contain what has been referred to as declarative knowledge, but it contains declarative knowledge in a semantic-web like structure that is inclusive of contextual information that influences activities on the part of the user. These definition maps are initiated by the mapper through the use a of a mid-range probe to jump-start the process. The scenario itself and the probe can be thought of as "cognitive anchors" that facilitate problem-based learning processes which emphasize the social construction of knowledge. As the map continues, there are opportunities for the "knowledge board" to ask additional apropos probe questions as well which are mapped into the closest related concept cluster.

The goal has been to create an environment for knowledge elicitation that facilitates active and spontaneous access of knowledge (without being told), Bransford, Sherwood, Hasselbring, Kinzer, & Williams (1992). This type of knowledge – when elicited – shows condition-action pairings that have been bound and remembered with respect to actual problem states, challenges, or difficult bottlenecks a person has encountered. Once a person starts to "generate knowledge" it typically pulls out a natural neurologically-based cluster of related concepts that are mapped on whiteboards or large sheets of paper for the mappee to "see". As the map begins to form, it substantiates the idea of a perceptual anchor (McNeese, 2000) consisting of *knowledge as concepts* (McNeese et al. 1990). We have referred to this process as "see what you think" or one that externalizes a person's mental model. However, the hope is that the concepts within a person's mental model will be grounded in situated events and therein elicit insights about the context (e.g., the behavioral shaping constraints). When ecological etchings are compacted into a concept map, one obtains what we have referred to as an "ecography" (Zaff, McNeese, & Snyder, 1993). So our view of CM is that you have a "mapping agent" visually represent in front of you “the things” that you use to identify and solve problems. This first mapping then typically deals with things that are not really temporal or procedural but is driven more by problems, definitions, connections and associations that a person heeds given their belief system about x^n.

The concept definition map is fine for front-end work in cognitive task analysis and in fact may be used to propagate other more sophisticated cognitive structures such as abstraction hierarchies (Rasmussen et al 1994), human performance models (Bautsch & McNeese, , 1997), in addition to design storyboards. However, one of the limitations we discovered is the necessity for associating specific knowledge with temporal sequences. In turn, the procedural concept map was created to connect clusters of knowledge with a sequence of procedural steps or temporal timeline of events (McNeese et al 1990). This method also provided a segue into the design storyboard technique as design storyboards emerge via a scene that progresses over time “frame-by-frame”. Therein, in addition to definition maps we added procedural-based maps to our repertoire to capture concepts related to a sequence of events. Note that this bridge between concepts and storyboard frames (across time) also intersected another component of our techniques: the scenario/script. When we had experts create a scenario, they socially constructed knowledge about a scene around a problem or critical incident that emerged over time (i.e., it is laid across a time sequence with a given unit of measurement, e.g.,minutes). The procedural concept map addressed some limitations of the definitional map as it provided a means to address issues that focused on temporality, event sequences, and an emerging problem space that created a trajectory into the future. One limitation, however, was that most of our procedural maps tended to be linearly sequential and therein rigid and inflexible to other forms of temporality and sequence (non-linearity, chaotic, timing patterns coupled to recurrent events).

4 Current Applications and Interests

The application of AKADAM to various real world domains has spanned across design teams, fighter pilots, command and control operations, helicopter operations, etc. (see McNeese et al 1995). However, our current operations tend to center more on homeland security concerns (emergency crisis management, image analyst operations, intelligence analyst operations, dispatch centers). We now view AKADAM as residing within part of the general Living Laboratory Perspective, as mentioned earlier, (McNeese, 1996; McNeese, Perusich, & Rentsch, 2000; McNeese, in press) for conducting cognitive systems engineering. The focus for the rest of this paper is centralized on the operational domain of hurricane crisis management (Brewer, 2004) and how concept mapping is currently evolving for this domain use.

Temporal events are critical in emergency response activities for all types of crises and disasters. Concept mapping sessions using mission scenarios were conducted with emergency managers in South Carolina and Florida. These concept mapping sessions were aimed at eliciting the task structures employed by emergency managers, while also building up a concept definition map of the types of information and activities involved within their work. A general overview about the knowledge elicitation procedure appears in Brewer (2002). Related to this study, the research centered upon eliciting expert knowledge about the process of preparation, preparedness, response and immediate recovery by state and county level emergency operations centers when a hurricane made landfall in the state. Teams of emergency managers were led through the same scenario so that comparisons of collaboration between team members, and identification of differences within job responsibilities could be compared. The linear concept map was based on the previous work done for AKADAM with pilots. A noted difference that has led to extensions of the approach involves the temporal scale at which the two types of linear concept maps were created.

In the case of the pilots, a linear scale was highly appropriate because it included only a short time window for task completion (from the time a pilot noticed a threat until it acquired the target within his targeting system). This time span was on the order of seconds to minutes. In the case of linear temporal concept mapping, with emergency mangers responding to a hurricane, the time line stretched from the beginning of hurricane season (early June) and narrowed to time span from 72 hours before landfall until 24 – 72 hours after landfall. The longer time span increased the opportunities for variance and external forces to enter into the crisis situation, fundamentally changing the nature, type and duration of the emergency manger’s tasks. This recognized limitation in a solely linear based concept mapping activity led us to rethink the methodological approach and offer forth alternative suggestions for how concept mapping can be used as a knowledge elicitation technique for temporal tasks and scenarios. We still believe that for short tasks that occur within a relatively short timeframe, that linear concept mapping might be most appropriate, but for larger scale events and tasks, other approaches could potentially yield more accurate results. A proposed typology is highlighted in the next section.

5 Progressing Towards the Future

Time is an element that is ever-present in all human activities. Unfortunately, temporal components are often omitted from characterizations of activities and events because of the difficulty in its representation. Within knowledge elicitation activities, by focusing on time directly, we have the opportunity to improve our understanding of not only the nature of time, but also in the influence it has on human activities. Below (Figure 1) we outline a first pass at classifying temporal activities for the purposes of eliciting expertise on tasks and scenarios.

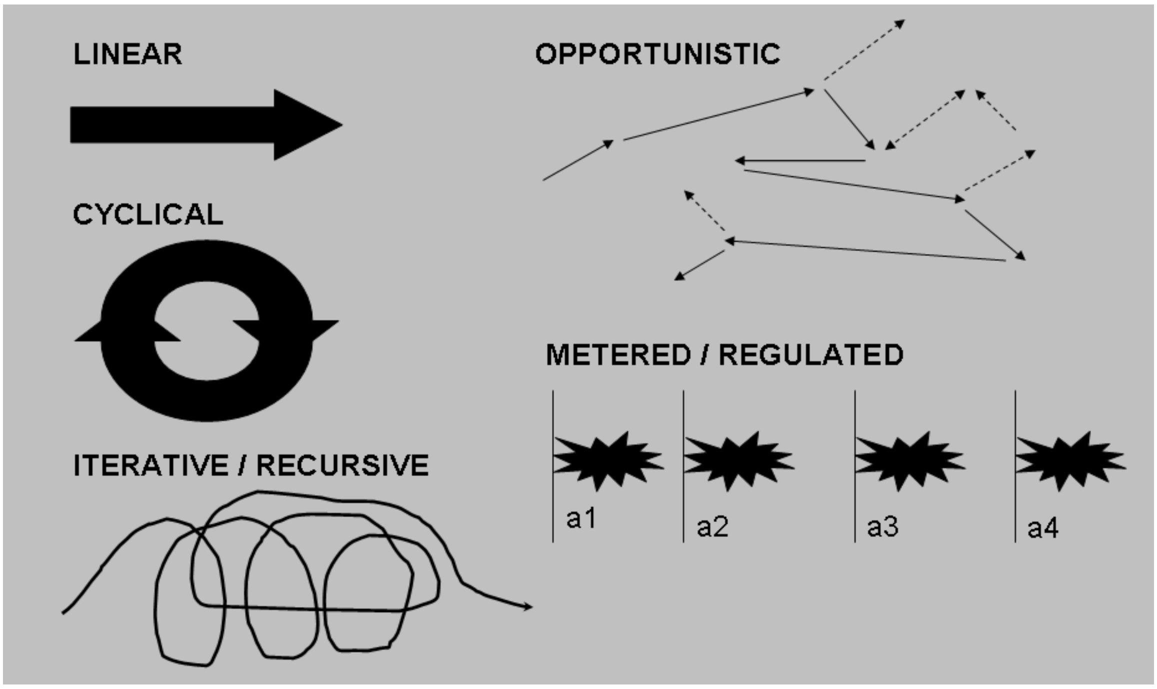

Figure 1: Preliminary Typology of Temporal Intervals

For each of the representations of temporal activities above, the lines represent the person doing the task required. Each line is then propagated with concept maps related to the temporal component. For example, in the linear concept map, time can be captured on a concept maps as events which occur before another event, yet the duration of time in between events has no representation (figure 2).

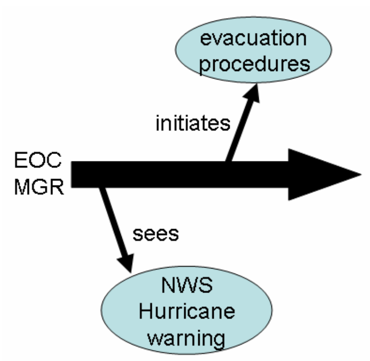

Figure 2: Simple Propagation Example

For linear temporal maps, the tasks should have short durations. An example of an appropriate task for using linear concept mapping would be analyses of gestures between two individuals for communication, human computer interaction research of mouse and keyboard inputs, etc. Cyclical time would be for activities with a range of temporal duration. It would be appropriate for eliciting knowledge from scientists or weather forecasters who deal with seasonal changes, diurnal changes, El Nino cycles, tidal influence, or lunar events. Iterative or recursive time could be used for analyses of software designers, engineers, industry experts, or scientists conducting experiments. Opportunistic temporal concept mapping would be appropriate for decision making tasks that have a lot of if/then variables and or paths of least resistance. Examples could include medical diagnoses, court proceedings, or economic patterns. Finally, the last type, metered or regulated involves temporal situations where an activity happens with direct repercussions until another event occurs which completely ends the first event and creates a new event. The numbered items are the ‘anchor points’ discussed previously. Eliciting knowledge via scenarios of work would be appropriate for this method, as would eliciting knowledge from actors, musicians, or movie-makers. This first pass at different temporal anchoring schemes for knowledge elicitation is, by nature, transitional. Like all things, it has room to evolve and develop over time.

These schemes then highlight more of the procedural and episodic components of memory, emphasizing how specific temporal knowledge patterns are inherent in the fabric of work settings. When these temporal patterns are coupled to the more traditional forms of concept mapping that emphasize the declarative contents of knowledge, a more comprehensive understanding of cognition in context can emerge. This is what we have discovered in the hurricane management center research. In turn, this more broader understanding can be used to leverage more veridical models of teamwork while enhancing the effectiveness of envisioned designs.

In conclusion we have looked at a variety of concept mapping ideations and schemes, focusing on differing ways concept maps have been used and adapted for unique situations. Inherently, the issues surrounding episodic events and the temporal patterns of work have driven innovative forms of concept mapping that extend the AKADAM techniques in new ways. This has been demonstrated for one of our domain applications in homeland security, hurricane crisis management.

Acknowledgements

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CONCEPT MAPS APPLIED TO MARS EXPLORATION PUBLIC OUTREACH

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Abstract. This paper describes CMEX Mars, an effort to create a comprehensive set of concept maps to describe all aspects of Mars exploration. These concept maps, created using the CmapTools software developed by the Institute for Human and Machine Cognition, are available on the Internet at http://cmex.arc.nasa.gov/CMEX and are linked among themselves as well as to resources on the Internet. The work described took place mainly between 1998 and 2001 and combined the goals of: 1) developing a library of concept maps for educational outreach, while also 2) refining the capabilities of the software used to create the interactive maps, and 3) making them available on the Internet. Here we focus on the library of Mars exploration concept maps that has been created.

1 Motivation

Space exploration programs are by their nature highly interdisciplinary. Many advanced technologies are brought together in space flight projects to achieve a range of interrelated science goals, usually in several disciplines. As public interest in the recent Mars Exploration Rovers attests, Mars exploration wins a wide audience by virtue of its extraordinary technical challenge, the exotic nature of its targets, and the profound importance of its astrobiology goals. The public information project described here was motivated by a belief that concept maps (CMaps) would be an effective way of satisfying the needs of members of the general public who might wish to penetrate more widely and deeply into the subject than is generally provided by an individual website.

The phrase "*not* rocket science" is a colloquialism used in the United States to describe a task that does *not* require extraordinary skills. The implication is, of course, that "rocket science" is beyond the understanding of

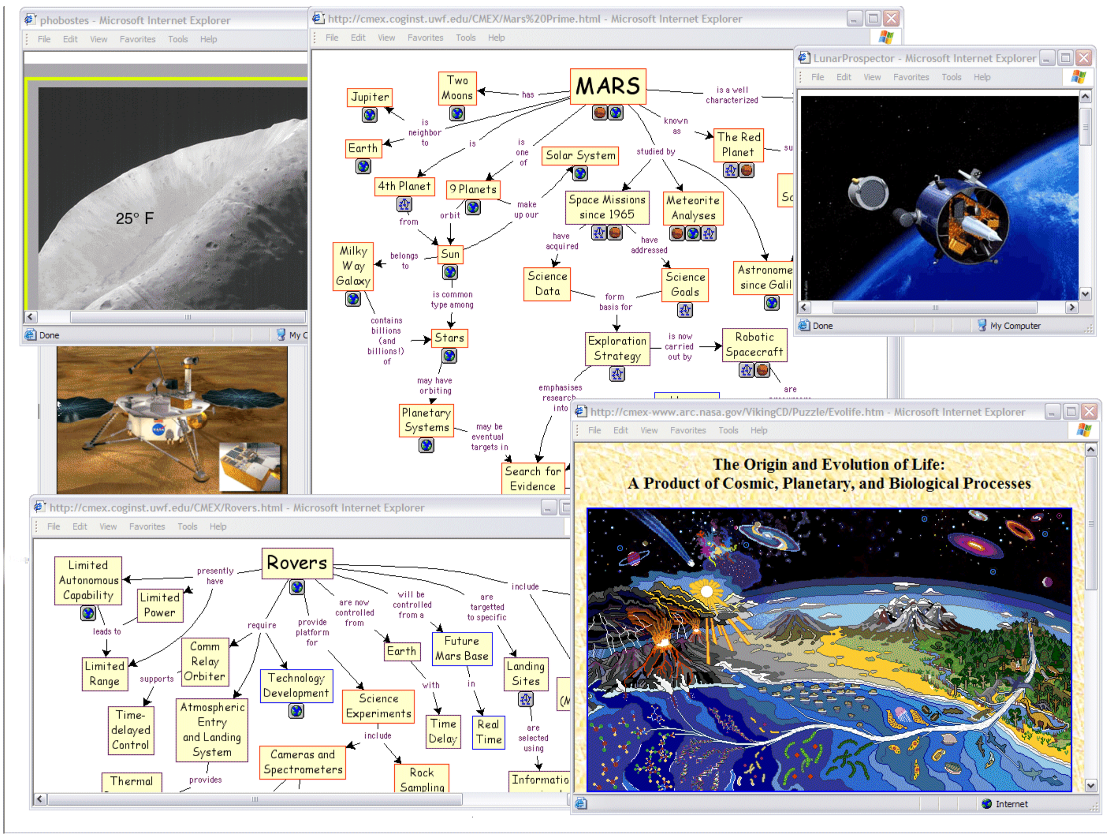

Figure 1. Most elementary Mars concept map (MARS) and associated resources.

mere mortals—an endeavor that approaches magic in its execution. Obviously this isn't true but, indeed, space missions are unusually complex and do require a considerable range of skills in many technical and scientific disciplines. It is through disciplined organization and experience developed over many decades (and which clearly still has room for improvement) that the necessary skills are brought together toward an end result that is frequently a source of great pride to the immediate project team and to the wider interested audience.

Because the now worldwide space exploration program addresses questions that attract keen interest far beyond the ranks of the participating scientists and, also, because the science disciplines and enabling technologies are so diverse, it is clear that the potential for educational outreach is large. This is especially so in the United States where scientific literacy is seriously lacking; as witnessed by the organized opposition to the teaching of biological evolution in schools. Although there is a mass of information about individual space missions and different aspects of space exploration available on the WWW, this information is not organized to allow an interested teacher or student to gain more than a shotgun perspective of the broad interdisciplinary field. Using the concept mapping software CmapTools (Cañas et al., 2004), a group from the Center for Mars Exploration (CMEX) at NASA Ames Research Center, in collaboration with the Institute for Human & Machine Cognition (IHMC), have sought to change this situation by creating "CMEX Mars," an ever-broadening tree of concept maps (totaling more than 100) on the subject of Mars exploration. This tree allows users to work their way from the most basic information to a level of detail that is intended to fully satisfy their interest. In principle, concept maps alone could provide unlimited detail but, because the Internet is now so rich in information it is much more efficient to supplement the concept maps with links to the most informative sites on the Internet. Thus, the concept maps are intended to provide summary information at different levels of detail as well as an organized list of Internet links to allow further penetration.

Mars Exploration Concept Map Contents

Exploring Mars	**Science**	**Geology**	**Geologic Processes**	**Climate**
Mars Introduction Planet Mars Mars Exploration Meteorites from Mars Myth & Science Fiction	Science Goals Comparative Planetology	Geologic History Geochronology Gravity Field Magnetic Fields Earth's Moon Gamma Ray Spectroscopy Recent to Current Water Activity Surface Chemistry Surface Layer	Impacts Volcanism Tectonism Valles Marineris Polar Caps Outflow Channels Valley Networks Paleolakes Recent to Current Water Activity New Martian Landscapes	Climate History Mars Atmosphere Earth's Atmosphere General Circulation Dust Storms Polar Caps Ozone Long Term Changes in Orbital Spin & Dynamics
History of Water	**Search for Evidence of Life**	**Life**	**Where to Search**	**Candidate Landing Sites**
History of Water Ancient Groundwater Modern Groundwater Ancient Surface Water Outflow Channels Paleolakes Valley Networks Long Term Changes in Orbital Spin & Dynamics Water Functions Water2 Water Molecule	Search for Evidence of Life Planetary Protection Mars Meteorites Astrobiology: The Study of Life in the Universe	Life on Earth Essential Requirements Life Tree of Life Unity of Life Limits of Life Water Functions Microbial Fossil Record Micro-organisms	Modern Groundwater Recent to Current Water Recent Volcanism Subsurface Exploration Deep Access	Site Selection Landing Site Hazards Gusev Crater Terra Meridiani Apollinaris Eos Chasma
Robotic Missions	**Orbiters**	**Landers, Rovers, Sample Return**	**Other Missions**	**Human Missions**
Interplanetary Spaceflight Mars Space Missions Deep Space navigation Robotic Outposts Planetary Protection Post 2003 Mission Plans	Orbiters Mariner 9 1971 Viking Orbiters 1976 Mars Observer 1992 Mars Global Surveyor 1996 Mars Climate Orbiter 1998 Mars Odyssey 2001 Mars Express 2003 Post 2003 Plans	Landers Rovers Sample Return Viking Landers 1976 Mars Polar Lander 1998 Pathfinder 1996 Sojourner 1996 Mars Exploration Rovers 2003	Airborne Platforms Airplanes, fixed wing Mars Aerodynamics Subsurface Exploration Deep Access Post 2003 Plans Robotic Outposts	Human Exploration Eventual Habitation Habitability Goals Cultural value Economic Value NAS Committee Report
Technology	**In Situ Resources**	**Other Considerations**		
Technology Development Aerocapture Power Surface Mobility Autonomous & Adaptive Operations Autonomous Control "Remote Agent" Biology-based Technologies Image Processing Pixel Array	In Situ Resource Utilization Atmosphere Rocket Propellant Surface Chemistry Minerals Ores Building Materials	Earth Analog Studies at Haughton Crater Practical Calendar for Mars		

Figure 2. A full listing of all the Mars concept maps.

2 Approach

The CMEX Mars concept maps are structured in a hierarchical form with the most general map, the MARS concept map shown in Figure 1, at the apex of the pyramid. An index to the set of concept maps is provided as a simple listing, shown in Figure 2, because the set of concept maps far exceeds the number that can be displayed in the form of a high level concept map sized to fit on a typical computer monitor.

2.1 Single Map Display

In principle, the entire set of concept maps could be linked into one giant concept map but this is a problem when working in two dimensions and with the display capabilities of a computer monitor. In creating the concept maps using an ordinary desk top computer (a Mac) with a modestly sized monitor (17 inch), the scope of an individual map is constrained to contain no more than about 30 concepts. This assumes that one wishes (as the author of the Mars concept maps does) to be able to see the entire concept map without the need to scan beyond the borders of the screen.

Typically, each concept map is linked to a number of others so that the total number of paths that may be followed according to the particular interest of the user is *very* large. Links are activated by clicking on an icon attached to the concept in question.

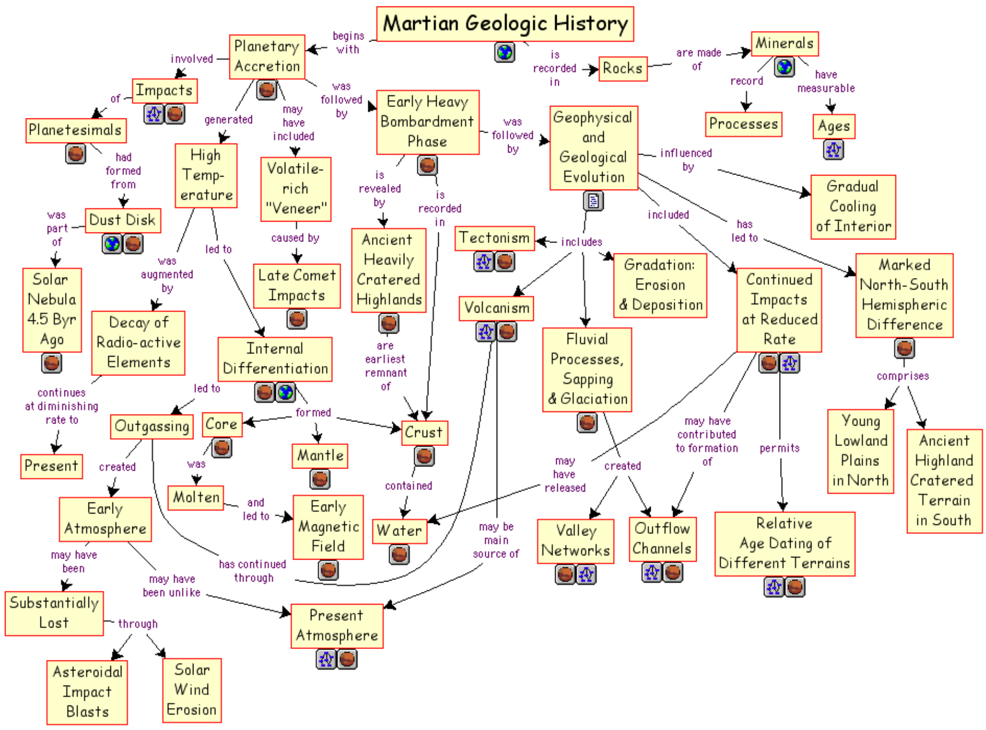

Figure 3. Geologic history (example of detail-level 1 science).

Figures 3 and 4 show examples of the increasing levels of detail that are provided by the concept maps. Thus far, the concept maps have been made to cover three levels of detail (Figure 5). The information content of a given map at the greater levels of detail is similar to what would be contained in the abstract to a science paper, that is, a basic summary that in most cases is expected to meet the interest of a general user.

As a practical matter, in order to maintain the legibility of the concept maps, the links between concepts (i.e., the linking phrases on the concept map itself, *not* the link between concept maps) are limited to the most important, and the layout of the maps inevitably tends toward a tree-like form. Figure 6 shows such a concept map. Figure 7 shows one that is less tree-like, capturing the inherent strength of the concept mapping form of information presentation. To some extent legibility issues may limit the value of the concept maps because, of course, it is the linkages that make a concept map more powerful than a simple PowerPoint-like listing. This

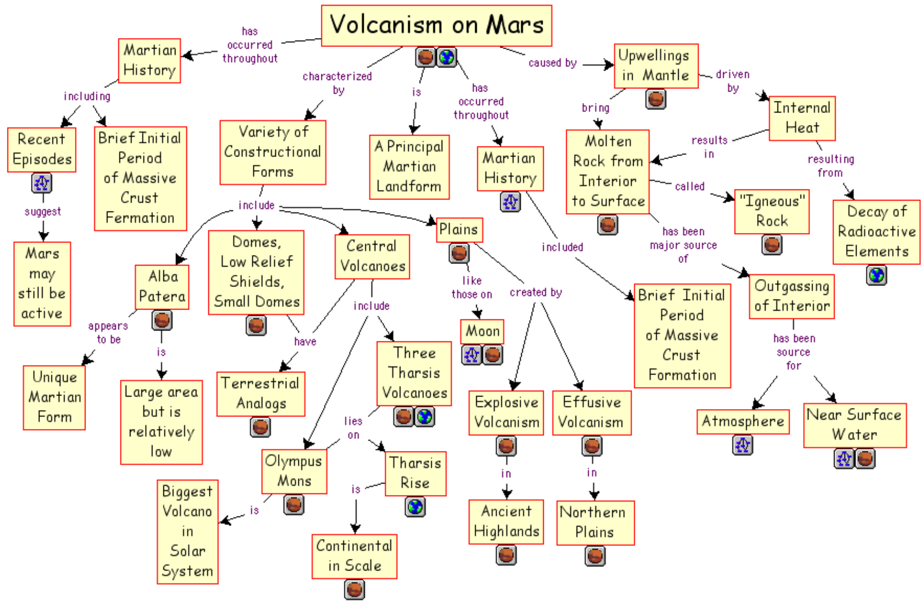

Figure 4. Volcanism on Mars (example of detail-level 2 science).

limitation is offset by the software links that are provided by clicking on the icons attached to concepts. These links effectively introduce a third dimension to the otherwise two-dimensional concept maps.

Also, toward providing visual ease in using the concept maps, a lot of thought and trial and error went into the colors and fonts used in their design. In principle, color can be used to provide additional information but we have decided to forego that opportunity for the sake of overall simplicity. Whether we were successful in our choices is a matter of individual taste.

We have also considered the use of images as an integral part of the concept maps both to provide information and to add visual interest to the maps. Thus far, given that we have already taken advantage of most of the 'real estate' available on each map, we have not been able to add images in a way that avoids clutter. Images associated with the concepts, therefore, have to be retrieved by clicking on the icons.

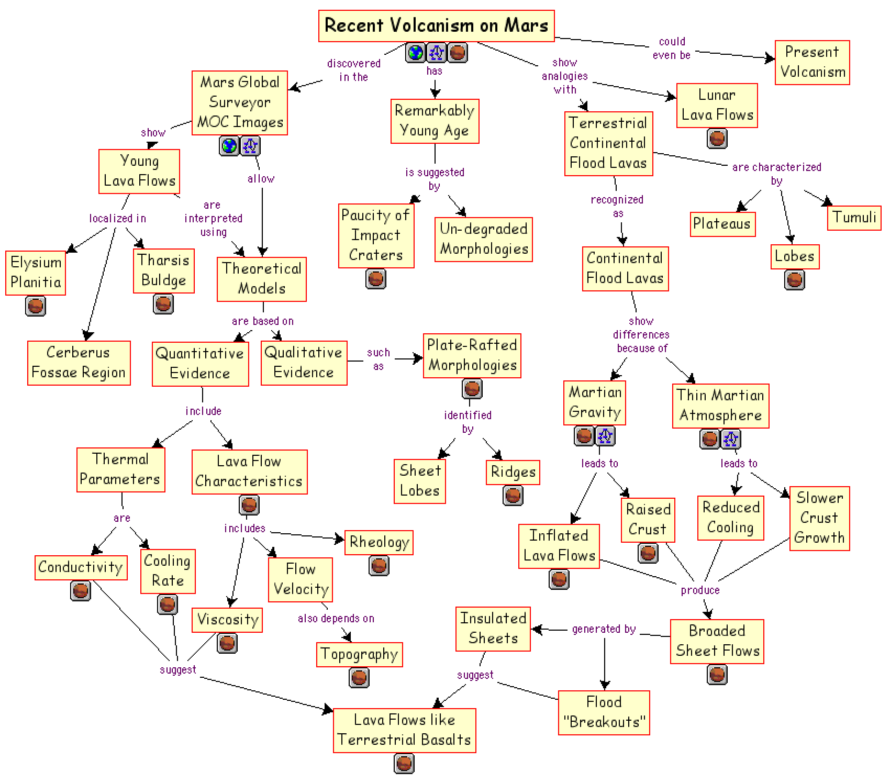

Figure 5. Recent volcanism on Mars (example of detail-level 3 science).

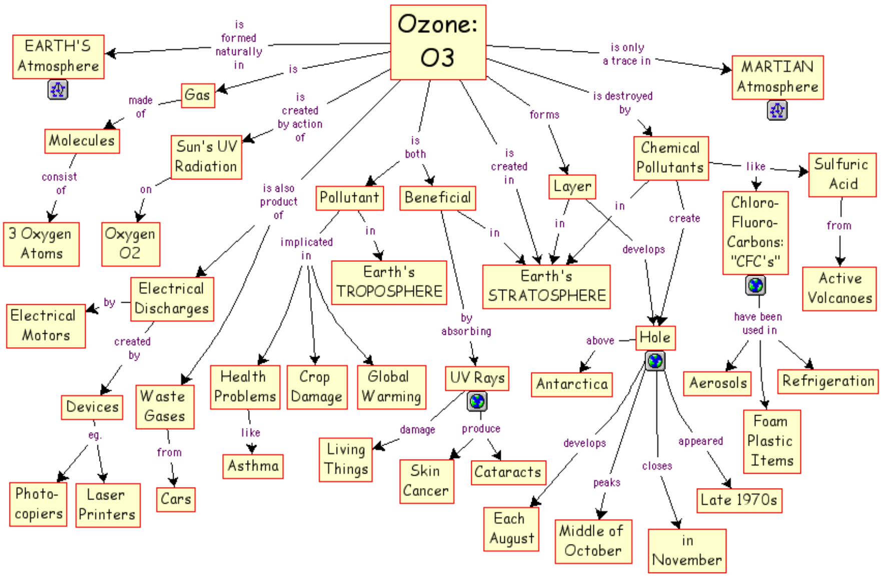

Figure 6. Ozone (concept map that is generally tree-like in structure).

2.2 Live Web Reflections

As this work was part of an international educational outreach, we had little knowledge of the end user (the students and teachers) computer speed, or even platform. This also meant we could not assume that a school would have any access to the World Wide Web (WWW) or that it could support infrastructure to connect via an intranet. Conversely, if a school *did* have the networking resources, we wanted to enable them with as much concept mapping tools as possible.

To facilitate this, we created an HTML application that could be distributed as a set of web pages on a CD-ROM. A thin client allowed the creation of a single, multiplatform, shared partition CD-ROM. The CD

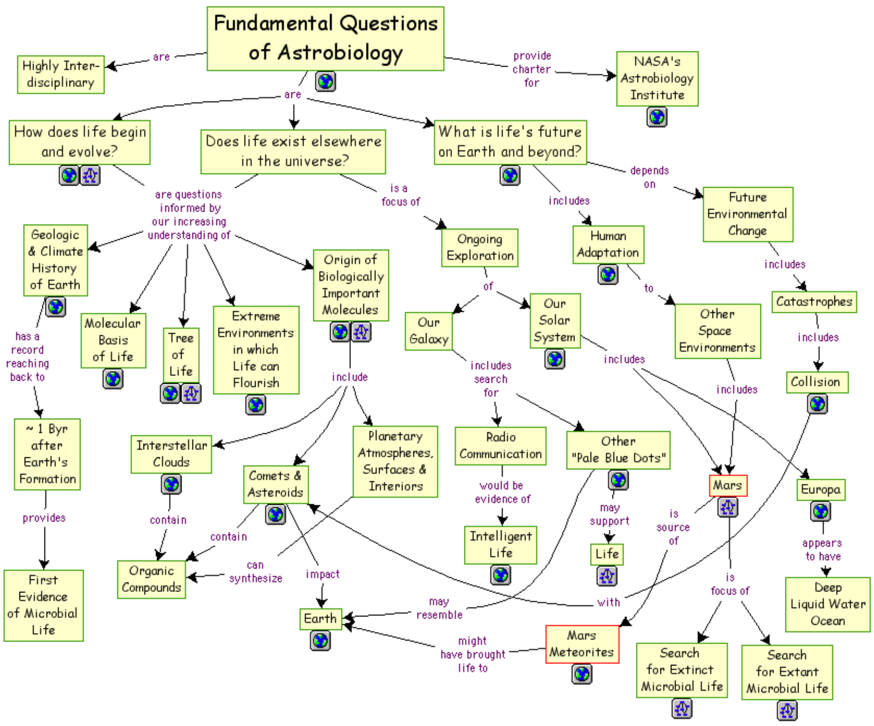

Figure 7. Fundamental questions of astrobiology concept map that is less tree-like in structure.

contained some 500 MB of Mars Orbiter Camera (MOC) images as well as several QuickTime Movies. With the concept maps as a thin client, we could easily share the maps and supporting multimedia on a single CD-ROM.

With maps being built in the modeling toolkit, we designed a special module for the toolkit in order to prevent concurrency problems. Map builders work and build maps in the same environment while web content is synchronized automatically by the tool. Deploying the CD itself was simply, and quite literally, distributing the website on a CD. Auto-start functionality launched the 'home' page when the disc was inserted into the computer.

3 Internet Links

A key feature of the IHMC CmapTools software is its ability to allow concepts to be linked directly to relevant sites on the Web. There is no limit to the number of sites that a single concept may link to; these sites are identified in a drop-down list after clicking on the Internet icon attached to a given concept (Figure 8). The Internet icon pictures the Blue Planet Earth. (The CMap in Figure 7 shows many such icons.) Each concept map has many Internet links (~1000 in total for this project) to sites where yet more detail is available on the subject (i.e., concept) in question. In this way the Mars concept maps are intended to provide access to a complete library of information to satisfy many nonprofessional needs.

3.1 Local and Remote Links

In addition to Internet links, the concept maps incorporate many links to material contained on the same server as the concept maps themselves, and that were included in the CD to allow students to build new maps from them. This material includes a variety of NASA reports, video clips, and an *interactive* Martian calendar. (Many have been proposed over the years—we, of course, like ours best.) The icon for these links pictures the Red Planet Mars. (The CMaps in Figures 3, 4, and 5 show many such icons.)

The Mars exploration concept maps are available on a server located at the NASA Ames Research Center in California. The CmapTools software used to generate the concept maps automatically saves a version of the new concept map in HTML format so that it can be accessed, in effect, as an interactive image. This allows users to browse the concept maps and directly link to the many websites to which the maps provide a portal.[1]

One of the challenges of establishing a web-based concept map library covering an active research area is the need to keep it up-to-date in light of new discoveries from data acquired by the various spacecraft orbiting and landing on Mars. The concept maps themselves require relatively infrequent updates because most provide basic information that changes relatively slowly. Given how much new data about Mars is being returned by spacecraft and how avidly the planetary science community devours that data, discoveries are made and new insights developed at an impressive rate. Some of these new developments lead to the need to amend one or more of the concept maps but, more generally, the new information can be incorporated by adding a new link to a site on the Web.

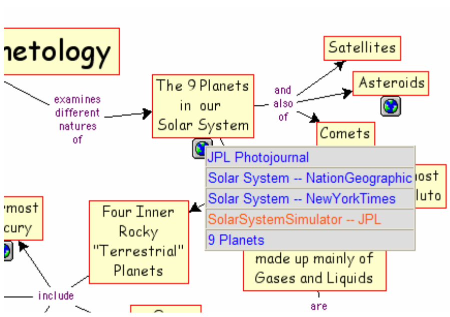

Figure 8. A close up of a set of links. Icons provide a menu of links to other concept maps and resources.

3.2 *On Searching and Indexing*

Concept maps provide a top-down browsing tool through the knowledge model. It has been shown that subjects can browse through these well-formed maps with less difficulty when compared to standard web pages (Carnot, Dunn, Cañas, Graham, & Muldoon, 2001).

The act of web browsing has been replaced lately with large scale search engines. That is, many web users rely on the large scale server farm indexing billions of web pages for them. Toward this end, the average search query, from a recent study, is 2.2 words (Spink, Wolfram, Jansen, & Saracevic, 2001). Google's popularity emerged largely due to their ranking system. Google's PageRank (Page, Brin, Motwani, & Winograd, 1999) is based on counting the number of hyperlinks pointing to the search candidates. The more links pointing to a website, the closer to the top of the search result list it appears. For example, the search in Google for "Mars Exploration" returns 1.3 million pages at the time of this article. The CMEX home page appears at the top, second to the Jet Propulsion Lab. The problem with the approach of most of the large scale search engines is they return the global maximum and are not built to return context specific relevant pages. Large search engines reflect the general familiarity of people across all ages and education levels (Shamma, Owsley, Hammond, Bradshaw, & Budzik, 2004); and as a result of their specific nature, many of the concept maps are ignored.

The maps represent a knowledge model; a well-formed set of linked concept maps and associated resources (Cañas, Hill, & Lott, 2003). Much work has progressed on how to link, index, and establish ranking for searching concept maps as well as the links to media, web pages, and documents they contain (Carvalho, Hewett, & Cañas, 2001; Leake et al., 2003). In particular, we continue researching how to leverage the topology and semantics of concept maps to index the maps and to search for information relevant to a map. This work is available in CmapTools and we are actively exploring its introduction into the HTML content.

4 Knowledge Modeling by the Expert

A characteristic of the CMEX set of concept maps and associated resources is that navigation takes place by browsing the CMaps constructed by an expert on the domain. Successful capture and sharing of human expertise depends on the ability to elucidate the experts' understanding of a domain, to represent that understanding in a form that supports effective examination by others, and to make the encoded knowledge accessible when it is needed in the future. This knowledge elicitation process is usually carried out by a knowledge engineer interviewing the expert, and is such a daunting challenge that it is referred to as the "knowledge acquisition bottleneck" (Buchanan & Wilkins, 1993; Hayes-Roth, Waterman, & Lenat, 1983) within the expert systems

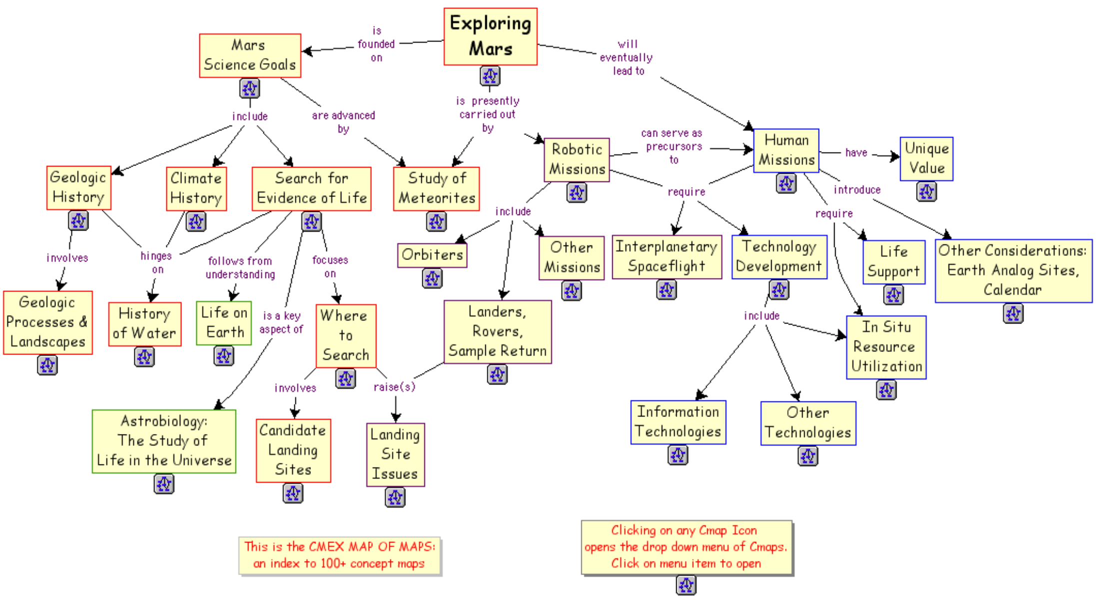

Figure 9. A map of maps.

[1] The maps are available at http://cmex.arc.nasa.gov, and mirrored at http://cmex.ihmc.us.

community. Even though the set of CMEX concept maps were not intended to be used as part of an expert system, the fact that they are based on the knowledge of an expert and were created by the expert himself without the aide of a knowledge engineer, speaks favorably of concept mapping as a knowledge elicitation and representation technique that is accessible to the expert, and of the CmapTools as a medium to carry on this knowledge modeling.

5 Conclusions

When this project got underway high speed access to the Internet was not common and so we chose to make the material available on a CD-ROM as well as via a server. More than a hundred requests for the CD have been received through the mail, almost all from high school teachers.

One clear conclusion we *have* reached is that a single concept map is not a good way to provide an index to a library of concept maps once the number exceeds about 30. Figure 9 shows the "Map of Maps" (MoM) in its original form. This concept map/index links more than two dozen subject areas that represent (this is, of course, subjective) the principal areas of science, technology, and mission information. As a practical matter it is difficult to incorporate more than about 30 concepts in a single map that can be viewed on a typical computer screen. So, it is not practical for the MoM to include (in the form of a separate concept) all 100+ concept maps that are available. Thus, each of the two dozen MoM concepts must serve as the portal to an average of five concept maps. Some of the MoM concepts serve as a portal to 20 concept maps. These can be accessed by clicking on the small icon associated with each concept. Figure 8 shows an example. In practice, a lot of hunting and pecking may be required to find the concept map that is of interest, and we have concluded that the index approach described earlier (Figure 2) is the preferred approach.

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Pamplona, Spain 2004

FROM INTUITIVE MAPPING TO CONCEPT MAPPING: AN APPLICATION WITHIN AN ANTHROPOLOGICAL URBAN FIELD STUDY

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Abstract. Concept mapping may be considered as the result of complex processes, which leads to the production of a concept map. Could it not be also used as a tool to explain mental representations, occurring during an anthropological field study? In an experiment conducted in Bordeaux the inhabitants were surveyed on the major transformation of their urban environment using concept mapping. It was also used as a means of interaction. For this particular purpose, concept mapping tools could be improved with new functionalities such as map superposition, layer-based readability ensuring that text does not move while the background is rotated, focusing and foregrounding technology…

1 Introduction

In anthropological field studies on as in urban culture, the anthropologist is brought to ask people about how they represent the things composing their daily environment. He thus obtains stories and/or drawings, more or less explicit. He works directly with the people themselves to characterize the relations between the elements (Winkin, 2001). In such anthropological searching processes, the main problem is to highlight invariants, to link or to separate implicit representations. The anthropologist must focus his attention on “the difference which the difference makes” (Bateson, 1972: 210). Particularly in this case, “we define concept as a perceived regularity in events or objects”.

The central point for investigations is a dynamic system, integrating realities and points of view. This system must be elaborated and displayed in a synthetic way, from an analytic process of identified relationships. The global shape of the system is obtained with the expression of axes, such as a Space-Time axis expressed in a Semantic axis (Revel, 2003). The Concept Map could be a precious tool to display such systems.

It is also a good tool to gather and transform a corpus of inquiry material. Stories given by actors of social events are collected according to a linear mode. The story is often conceived by the actor himself as a linear space: “A space time of the narrative fiction is a mimesis of the lived space time” (Revel, 2003). These stories are delinearized and spatialized in a semantic network. The research worker must create a symbolic form, in order to represent objects belonging to various planes simultaneously. On the other hand, graphic material such as spontaneously generated maps include tensions which are underlined both in graphic and word form. In both cases, it is the implicit mental scheme that we propose to represent.

The question is: How can a formal representation, such as concept map, be generated from the spontaneous productions of interviewed actors? One suggestion is to take into account the dynamic process of map elaboration: one locates opposable tendencies, such as attraction and repulsion, cohesion and dyscohesion, threshold and passage, limit and border... (Lussault, 2003). In this respect, the use of the "elastic" distance is productive. On the field, paper fragments are proposed to the person, who can identify them using letter, symbol, color, etc., place them on the drawing and move them to coincide with the account or the comment which is produced, thus establishing coherence among the various elements.

It is this part of the production of a conceptual space which we will study here, because the interaction between the searcher and the interviewed person needs to be based on a set of operations, which could be facilitated by functionalities of a data-processing tool. This paper describes an experiment of concept map production during an anthropological field study. The context and the operating mode of the experiment are exposed, and examples of concept mapping steps, given. The discussion concludes with suggestions of new functionalities for concept mapping.

2 Production of anthropological intuitive mapping

Bordeaux is a medium-sized city in the South West of France (720 000 inhabitants for the metropolitan area). After twelve years of “pilot” studies, discussions, projects and reports (various and varied), town hall set about building a tramway network. Work on the project lasted 5 years and transformed the city. On December 21st 2003, the tramway network was inaugurated with a mobilization of the local media. Taking advantage of this media-event, the study was carried out. On that day, people expressed readily their dreams for their city and their emotional reactions after a long wait. They also felt members of a community. From the point of view of cultural anthropology, we were interested in "the difference which makes the difference" (Bateson, 1972: 210). Several teams of researchers recorded on film how users first reacted to the novel situation. The reactions and gestural indications were also recorded through spontaneous, ten-minute interviews of about thirty people who were waiting at a tramway station. Along with data collection, the objective was to work out spontaneous maps which they could comment on and, as the interviews progressed, make more readable. The suggested emphasis was put on a primitive or ancestral vision of the city, seen as an urban organism.

These intuitive maps present deformations with regard to the real space, the known spaces are stretched out using numerous markers, the lesser known or lesser frequented spaces are underestimated. It is these deformations which interest the anthropologist.

Spontaneously, urban space is often illustrated in a form which can still seem analogical and related to a kind of geographic map (fig 1). The "blue moon crescent" in the centre is the usual representation of the river: the Garonne. But the story which accompanies it does not refer to a diagrammatic representation which could be included in a vertical projection: it is a typical urban landscape as seen from a pedestrian perspective with its recognizable landmarks: hills, church spires, bell-towers, etc. By the way, those kinds of landmarks are also proposed to structure the landscape of websites (Forsythe, Grose & Ratner, 1997). In our collected materials, it is thus the person who projects himself or herself in an improbable *topos*, since the place from which one can simultaneously observe reference markers would be a 500 meter-wide river. Among the collected words, some can be integrated into the chart, others, with metaphoric interpretation, explain the steps of the map elaboration. Here, the central point of perspective is in the map centre, and the city is organised as a circular ring which links markers together. When the representation is rotated, one can confirm that the city is organized around this virtual centre of rotation (what the anthropologist will interpret as the true heart).

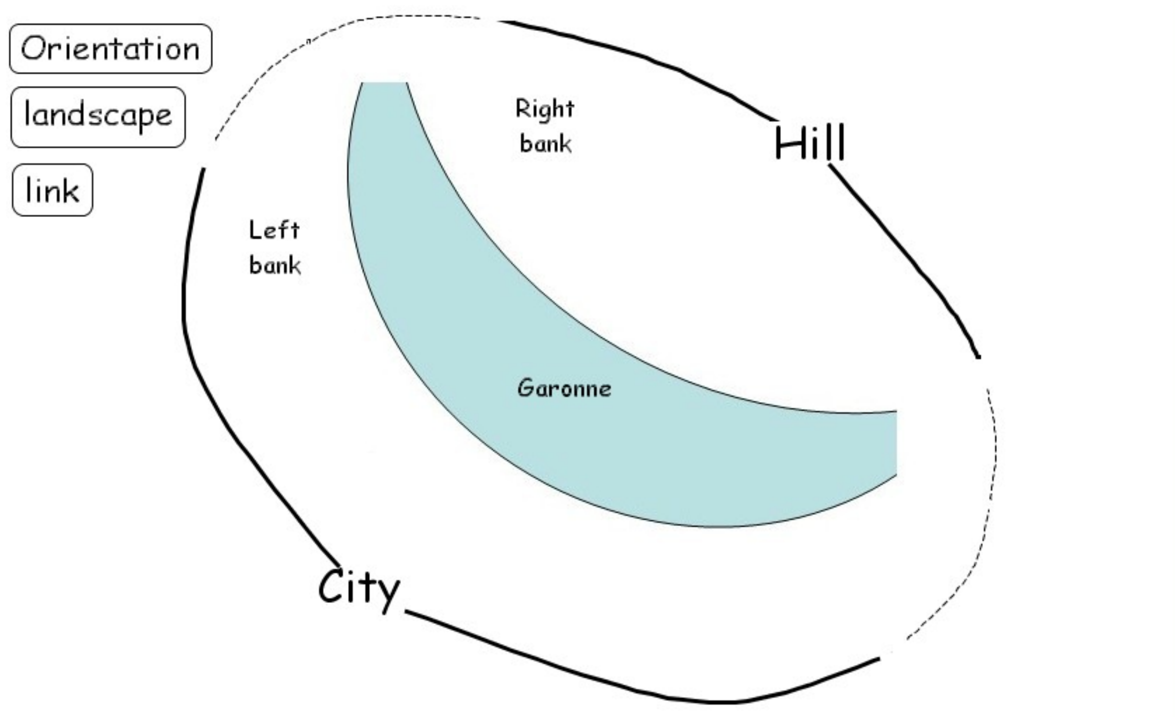

Figure 1. The city as an amphitheatre… or a landscape in which one can be oriented.

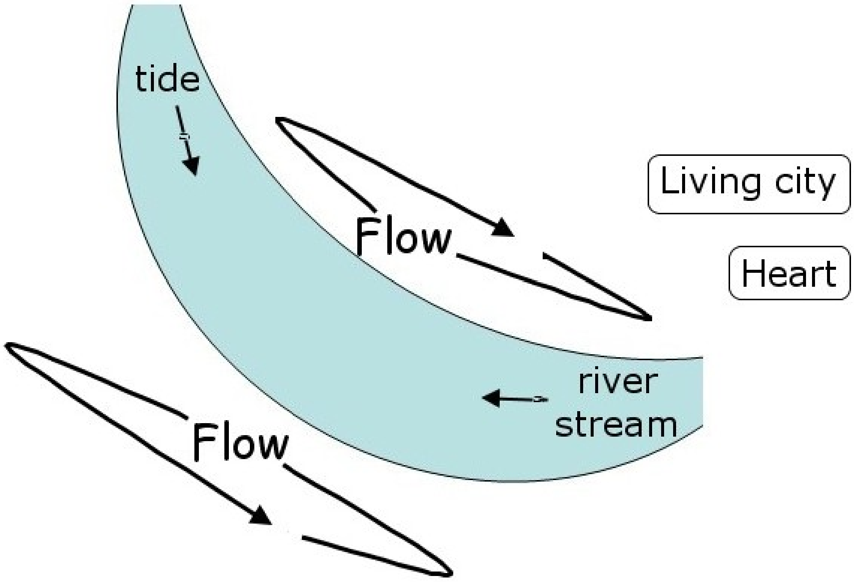

Figure 2. Flows of the city… and vital flow of a living heart.

Another aspect is the urban vital force expressed in the fig 2: the powerful and regular flow of the tide, a significant characteristic of this river, combined with the circular flows of human activity. The city (new, future) puts all these flows in close symbiosis. It is an organization which is described, and the word “heart” expresses the total pulsation, the continuity of a pump, but never a zone considered as the geometric centre of the urban space. From a symbolic point of view, the human multiform bustling arises from the fundamental metrorrhagic pulsation of the river, which is perceived as an urban organism. We would like to illustrate this alliance of rhythms through an animated superposition of circular links and alternative linear links.

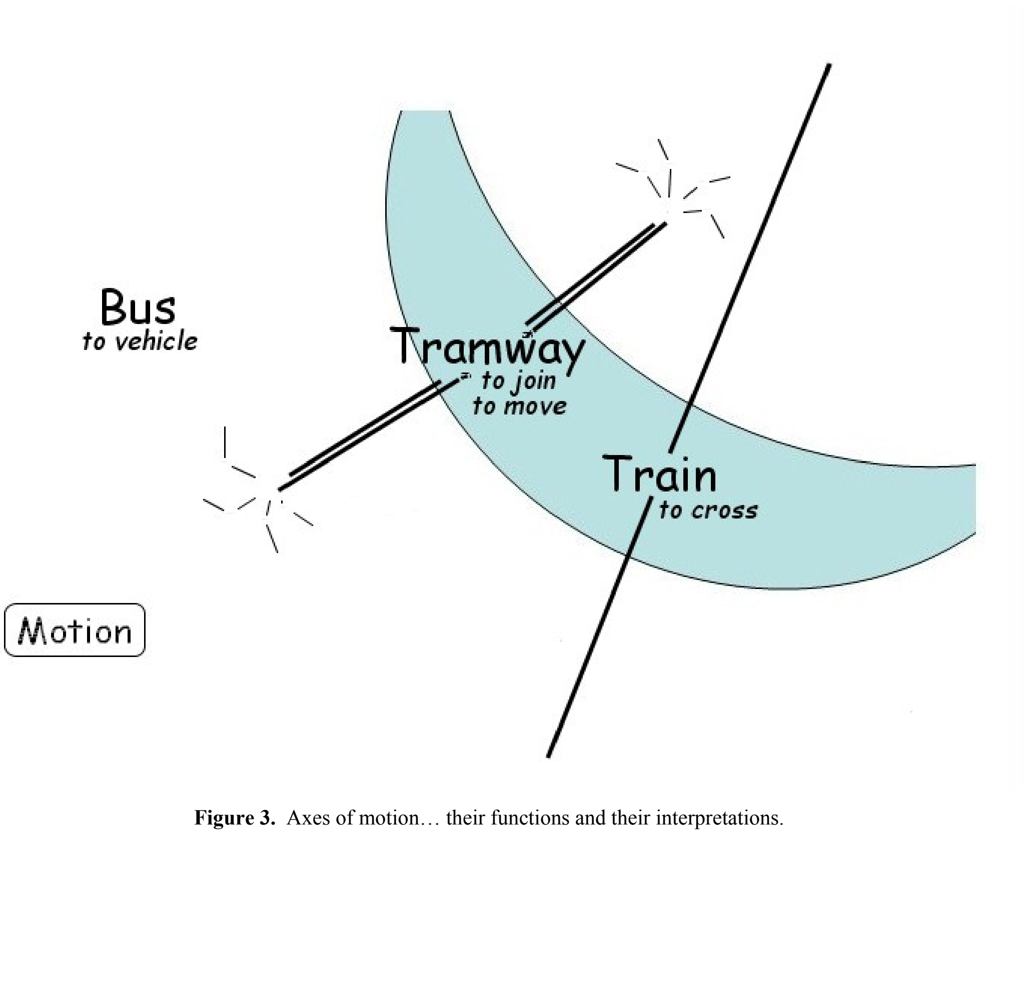

Figure 3. Axes of motion… their functions and their interpretations.

Another approach is related to the directions of the movements (fig 3). For example, the axis of the interurban train is judged as being outside the city. The train does nothing but cross the city and, thus, is perceived as tangent to the city. On the contrary, the tramway seems independent of a fixed axis: with its ramified network, it "serves even the smaller streets". It is assimilated to a moving side walk. In this urban mental landscape, the bus only transports people; it is not beautiful and cannot be inserted in the urban web. In fact, the tramway has the aspect of a train and the function of a bus. Like a bus, it is flexible and light, moves within traffic and represents an alternative for pedestrian, at the same time, like a train, it is rapid, safe and regular. In this humanized vision, the tramway acquires a symbolic dimension, relates to the human body itself and the desire for social bonding. Words such as motion (fig 3) should not be taken literally, but must be understood metaphorically: the tramway network akin to the human irrigation of a territory.

3 Concept map manipulations and expected functionalities

An anthropologist is not a psychologist. He is not interested in the productions of a single person. His objective is to produce a single concept map, which could be the reflection of a collective interpretation of a situation.

3.1 Map and concept superposing

Successive maps are built as recorded testimonies are confronted, analyzed and added. Their common points are brought closer and reinforced. To obtain an overview of what people imagine the tramway to be, we must make a superposition of all maps, in order to overlap all of these pieces of the human imagination.

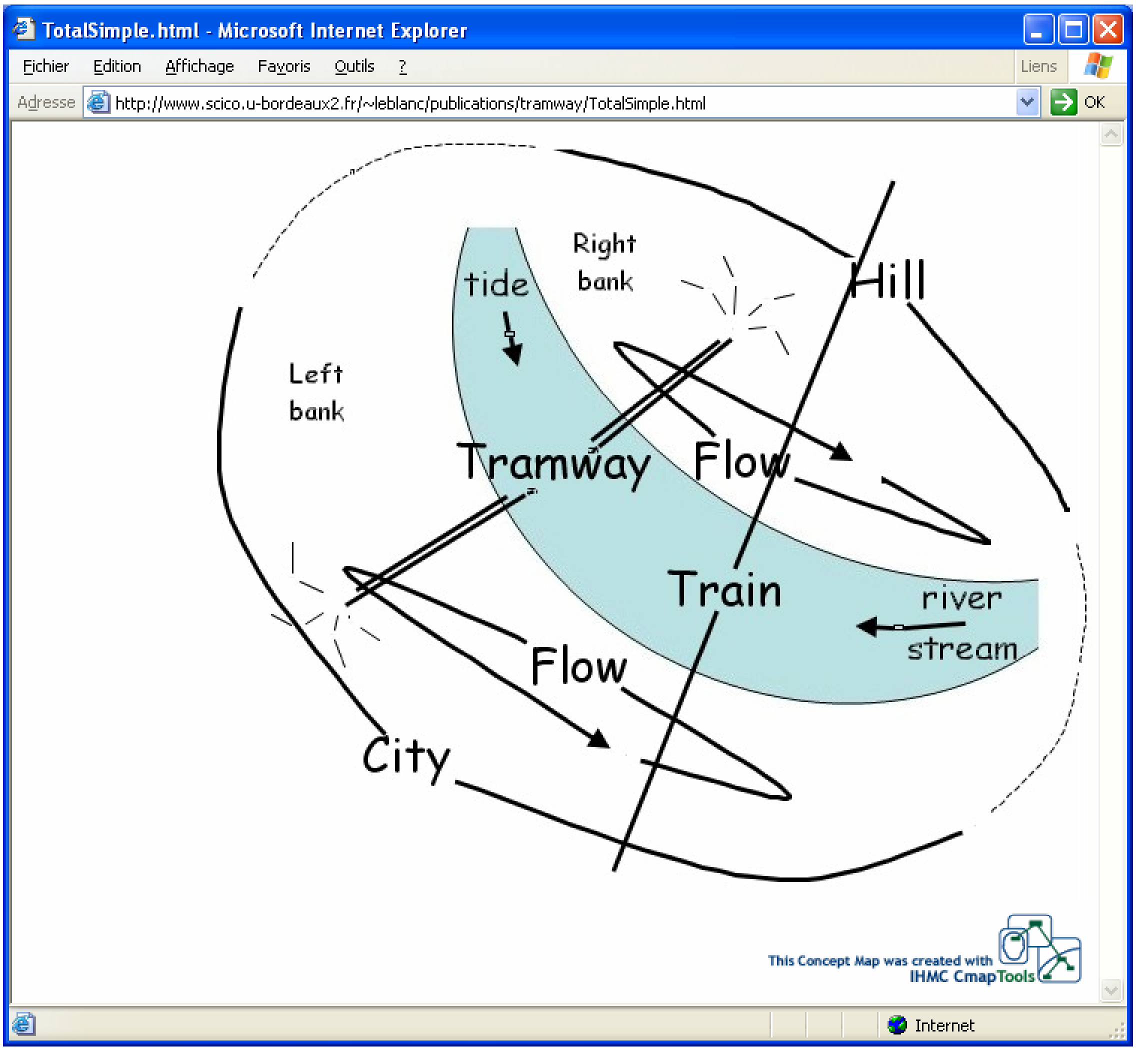

Figure 4. Synthetic pre-concept map.

To produce a synthesis, we assemble different dimensions over a single analogical background by superposition the forces with their tensions (fig4).

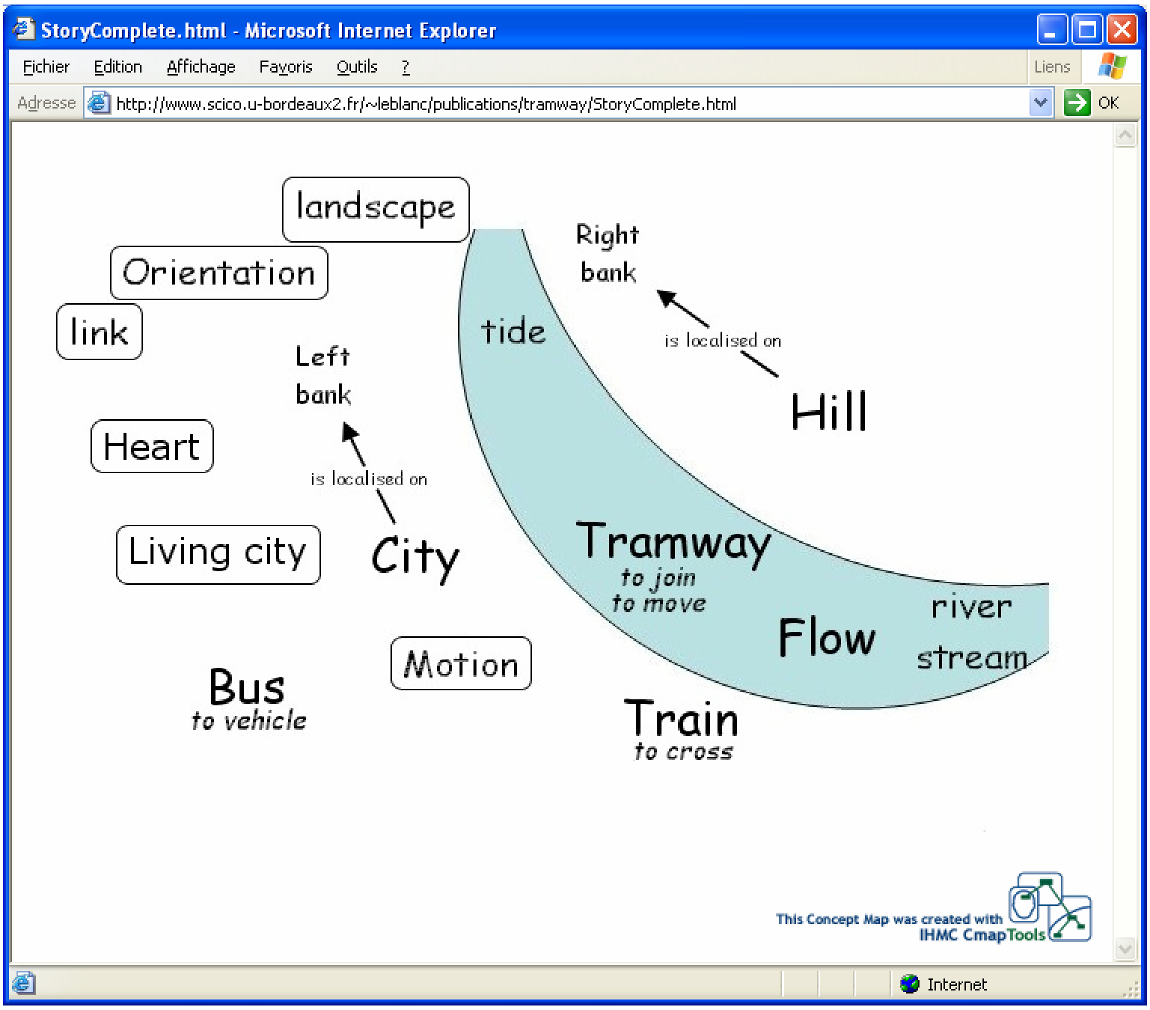

Figure 5. Synthesis combining form, figure and theme.

We then place the descriptors which could replace landmarks or functions from the analogical space to evoke a conceptual space (fig 5). In doing so, the anthropologist seeks to preserve part of the evocative force of the territory in a document which is still analogical, for example this shape of the crescent which is purely cultural, emblematic and is not the result of personal experience.

The common vision (which is in reality a representation of the community) could amount to: the streetcar unites two banks and several worlds including that of the present-day inhabitants of the city. In the commemorative stamp published on April 26th 2004, the painter Andreotto expresses the same feeling, and his design symbolically orders the sketch of a concept map (fig 6). We notice there that noun phrases extracted or reconstructed from narratives do not have the same status: some have a thematic value and refer to a primitive map (orientation, motion, living city).

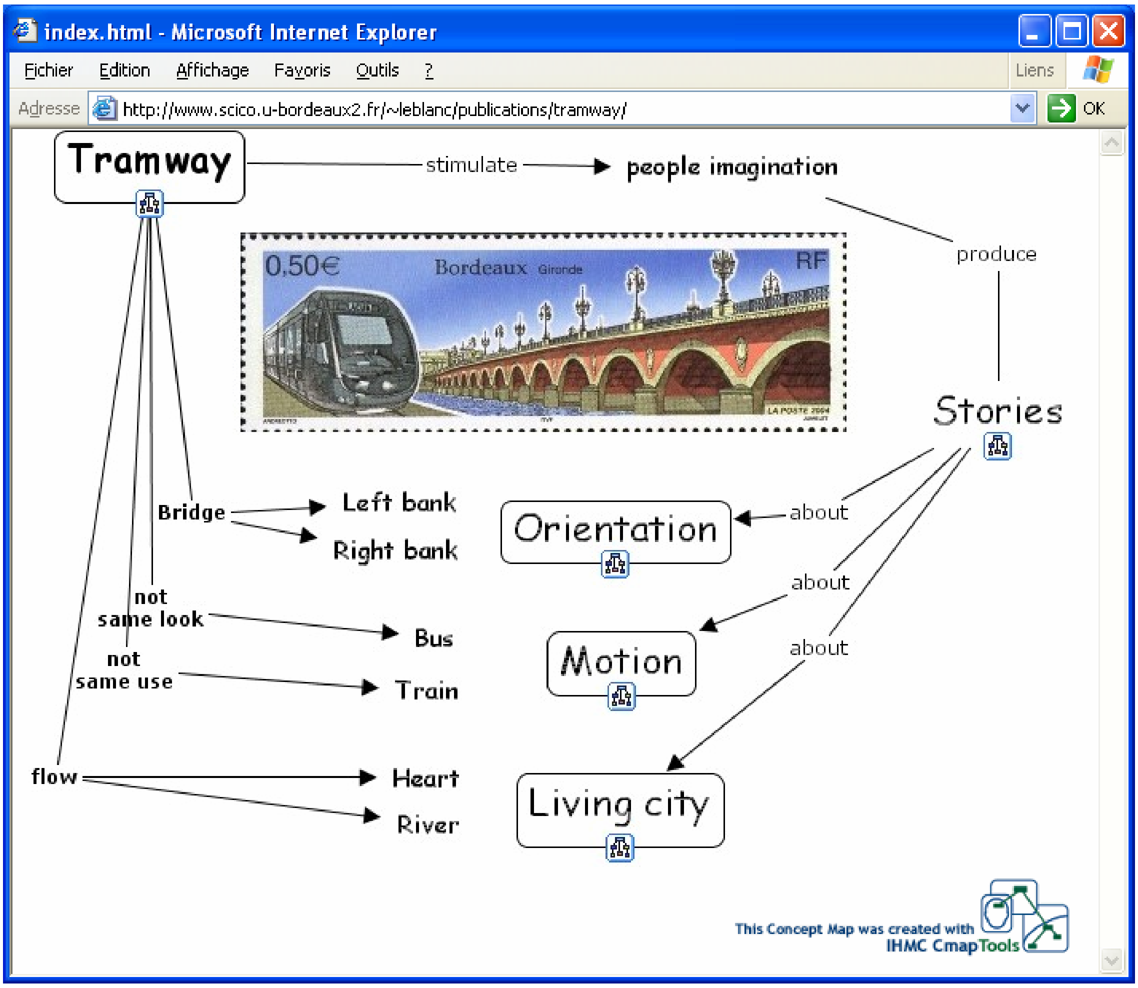

Figure 6. Towards a synthetic concept map.

3.2 Design related operations

We have used CmapTools software to generate all the above-mentioned figures. In the interactive phase of the inquiry the narrative arising from a dialogue takes hold of the map and brings it to life. At this point, it is necessary to be able to turn the map around an axis and, at the same time, to establish from what perspective the represented space is viewed: map, reality or viewer.

The superimposing or the interweaving of links must be possible, as if independent layers were stacked (Platteaux, 1994). How can we make sensitive the simultaneity of activities, places, according to rhythms which generate the territory as a whole? We want to be able to control the appearances and disappearances of elements which are contiguous in the time layers.

The question of metaphors is more delicate: aside from the polysemy of certain words (heart, motion), there are visual metaphors (the crescent) which evoke a cosmology consistent with the circadian rhythms of the tide, the moon, etc.

We could translate them graphically by granting the term a potential dimension which would not be present at the onset and brought to the surface using a pointer.

4 Discussion

It is as if, in some way, the stage of formal improvement established congruence between the thought landscape and the drawn landscape (Bateson, 1979). The passage from forms which are already abstract but make up a mental landscape to a system of spatially related concepts might entail losses and gains (Barth, 1993). In our case, it seems obvious that the inhabitants share a strong mental representation of their city. To break down its perceived dimensions and highlight its relationships to all kinds of entities shows its richness, but can make it lose its anchoring in a symbolic space system. It would perhaps be necessary to position the conceptual network upon a simplified analogical background, as outlined in the first figures.

In the relationship between of imagery and explanation or comment, let us distinguish (Vignaux, 1998: 60) that which originates from procedures of analytical processing (we describe, we decompose in order to recompose an idea or verbal image of a situation or a space) from that which composes with reality in a analogical way (we represent, we evoke, we draw, we create an image).

The analogical system of production accepts condensation, i.e. the summarizing of multiple sequences of explanations or instructions (Bresson, 1984). It is a process of schematization which produces a synthetic map; its analogical dimension disappearing only in the case of a conceptually “pure” space.

In this case (fig 5), the chaining of the concepts must remain limited; nodes could relate to complementary conceptual layers, devoid of any analogical references. This presentation could be more appropriate for certain cognitive styles, which are characterized by a holist construction of a thinkable space around a simple, self-evocating structure (Riding, 1997). One can also call upon a three-dimensional spatial representation or the use of layers with adjustable levels of complexity.

5 Conclusion and perspectives

The anthropological experiment is closely akin to common interpersonal communication: speech is prevalent on the temporal plane but can also give life to a two-dimensional space. While they are speaking, many people are happy to take a sheet of paper and, with their pencil, connect terms and objects together. In doing so, they find themselves simultaneously interacting on both levels. Especially when it is a question of expressing a strongly interiorized, inherited or mythological vision, like that of the city, an imaginary territory one also travels in dream. It would be useful to go deeper into the study of strategies which correspond to cognitive styles or to schematization profiles (Michel, 1993). In particular, the status of an intuitive map, produced in our scope, can get closer to that of a cognitive map (Me and my environment). The passage to concept map transforms the representation of an analogical space and allows getting closer to the mythical space, where the urban complex space-time becomes subsumed in a founding shape.

6 Acknowledgements

All of the illustrations from this paper are produced with the CmapTools software, downloaded from the IHMC Website at http://cmap.ihmc.us.

These illustrations are available on: http://www.scico.u-bordeaux2.fr/~leblanc/publications/tramway

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CMAPTOOLS: A KNOWLEDGE MODELING AND SHARING ENVIRONMENT

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Abstract. Concept maps are an effective way of representing a person's understanding of a domain of knowledge. Technology can further help by making it easy to construct and modify that representation, to manage large representations for complex domains, and to allow groups of people to share in the construction of the concept maps. CmapTools is a software environment developed at the Institute for Human and Machine Cognition (IHMC) that empowers users, individually or collaboratively, to represent their knowledge using concept maps, to share them with peers and colleagues, and to publish them. It is available for free for educational and not-for-profit organizations, and public servers have been established to promote the sharing of knowledge. The client-server architecture of CmapTools allows easy publishing of the knowledge models in concept map servers (CmapServers), and enables concept maps to be linked to related concept maps and to other types of media (e.g., images, videos, web pages, etc.) in other servers. The collaboration features enable remote users to asynchronously and/or synchronously collaborate in the construction of concept maps, and promote comments, criticism, and peer review. Public CmapServers have resulted in a large collection of knowledge models publicly available, constructed by users of all ages in a variety of domains of knowledge and from a large number of countries.

1 Introduction

Concept maps are a result of Novak and Gowin's (1984) research into human learning and knowledge construction. Novak (1977) proposed that the primary elements of knowledge are *concepts* and relationships between *concepts* are *propositions*. Novak (1998) defined concepts as "perceived regularities in events or objects, or records of events or objects, designated by a label." Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit. Concept maps are a graphical two-

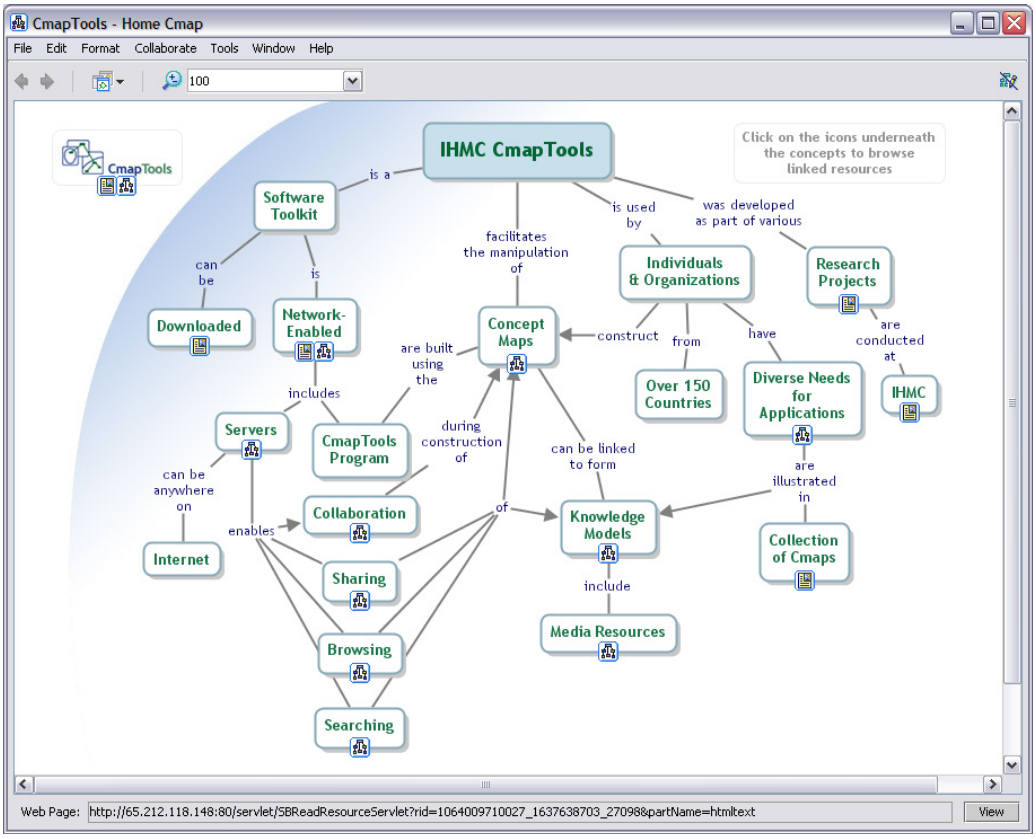

Figure 1. Concept Map about CmapTools (from http://cmap.ihmc.us)

dimensional display of concepts (usually represented within boxes or circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts forming propositions. The simplest concept map consists of two nodes connected by an arc representing a simple sentence such as 'grass is green,' but they can also become quite intricate. Figure 1 shows a concept map about the CmapTools software. 'IHMC CmapTools facilitates the manipulation of Concept Maps' is one of the propositions in this map. By convention, links run top-down unless annotated with an arrowhead. The vertical axis expresses a hierarchical framework for the concepts. More general, inclusive concepts are found at the highest levels, with progressively more specific, less inclusive concepts arranged below them.

Concept maps have been demonstrated to be an effective means of representing and communicating knowledge. When concepts and linking words are carefully chosen, these maps can be useful classroom tools for observing nuances of meaning, helping students organize their thinking, and summarizing subjects of study. From an educational perspective, a growing body of research indicates that the use of concept maps can facilitate meaningful learning (Coffey, Carnot et al., 2003). Concept maps have also been shown to be of value as a knowledge acquisition tool during the construction of expert systems (Ford, Coffey, Cañas, Andrews, & Turner, 1996) and performance support systems (Coffey, Cañas et al., 2003), and as a means of capturing and sharing experts' knowledge (Coffey, Hoffman, Cañas, & Ford, 2002).

Technology facilitates the construction of concept maps in the same way that a word processor supports the task of writing text. However, more powerful tools enable better management of large representations for complex domains, and facilitate sharing by groups of people in the construction of the maps. This paper describes CmapTools, a client-server based software kit developed at the Institute for Human and Machine Cognition (IHMC) that is designed to support the construction of concept maps by users of all ages, and to enable collaboration and sharing during that process. We begin by providing background information on CmapTools, proceed to list the objectives that led the design of the software, and then describe the software by expanding on these objectives.

2 Background

At IHMC, research efforts on concept mapping have two separate and distinct roots. The first has its origins in the use of concept mapping for knowledge elicitation. ICONKAT (Ford, Cañas, Jones et al., 1991), a toolkit for knowledge acquisition and the development of expert systems, had a concept mapping component. During the development of the nuclear cardiology expert system NUCES (Ford, Cañas, Andrews et al., 1991; Ford et al., 1996), the use of concept maps was extended beyond knowledge representation, to serve as the browsing interface to a domain of knowledge. NUCES used a concept map-based browser as the interface for the explanation subsystem of the expert system, as reported by Ford, Cañas, and Coffey (1993). This concept map-based interface provided a unique way of organizing and browsing knowledge about any domain (Cañas, Ford, & Coffey, 1994). Icons located right below some of the concept nodes provided access to auxiliary information to explain the concept in the form of pictures, images, audio-video clips, text, or other concept maps related to the topic. (The web had not yet been developed when this concept map-based browser was implemented.)

The second root has its origins in Quorum, a joint partnership between IHMC and IBM Latin America (Cañas, Ford, Hill et al., 1995). In Quorum, IBM's corporate computer network enabled collaborative projects between students throughout Latin American countries. (The Internet had not yet arrived to these countries when the Quorum network was implemented.) During Quorum we confronted a lack of software with a constructivist foundation needed to facilitate collaboration among students. We developed the Knowledge Soup (Cañas, Ford, Brennan, Reichherzer, & Hayes, 1995), which provided a unique type of collaboration among a group of users, usually students, each constructing a concept map on the same topic. The program automatically converted the concept map under construction to a list of propositions. The users selectively published propositions (we called these published propositions *claims*) to an aggregation or database of propositions from all students (and teachers) working on a particular topic –the Knowledge Soup— which resided on a server. It is through these Knowledge Soups that collaboration and sharing took place. Published claims were seen by other students and could be utilized in their own map-building process, but a student couldn't see *all* claims published by other students, as this would often be cognitively unmanageable. The only claims a student saw were those directly related to the ones he/she contributed to the Soup. As a student published more, a wider range of other related claims became visible. This strategy was intended to encourage and reward students for participation. A student could query or question a claim submitted by another student, if he/she disagreed with it or found it puzzling, and the originator of the claim could respond.

The lessons learned from these two efforts, together with the potential impact we envisioned a powerful software tool for the construction and sharing of concept maps could have in education and organizations, led to the development of the CmapTools software.

3 Objectives of CmapTools

CmapTools was developed with key objectives in mind:

1. *Low Threshold, High Ceiling*
   Myers, Hudson, and Pausch (2000) referred to the "threshold" as how difficult it is to learn how to use a system, and the "ceiling" as how much can be done using that system. Most systems have either a low threshold and a low ceiling, or a high threshold and a high ceiling. Our aim was to combine a low threshold (a system that can be learned in a few minutes and does not have an intimidating interface e.g., filled with icons surrounding the canvas, so that the user is able to concentrate on concept mapping), together with a high ceiling (an environment that supports the construction of large sets of concept maps by experts).

2. *Extensive Support for the Construction of Knowledge Models*
   Concept maps enable users to graphically express their understanding of a domain of knowledge. This representation can consist of a small concept map constructed by a child, or, in the case of a detailed representation of a domain, a large collection of related maps. In CmapTools, we refer to a set of concept maps and associated resources about a particular domain as a knowledge model (Cañas, Hill, & Lott, 2003). Our objective was to provide an environment that supports the development of knowledge models of all sizes, without limitations on where the resources and maps physically reside.

3. *Extensive Support for Collaboration and Sharing*
   The WWW was conceived by Tim Berners-Lee to be a global system to assist collaboration through hypertext (Berners-Lee & Fischetti, 2000). Unfortunately, it has turned out to be an environment where it is easy to browse (although not necessarily easy to find what one is looking for), hard to publish, and much more difficult to collaborate. Berners-Lee envisioned a system that would facilitate collaboration among scientists. We share this vision and believe that the best use of the Internet in education is to enable and foster collaboration among students. However, there continues to be a lack of constructivist-based collaborative learning environments. Similarly, scientists and other professionals have few tools with which to share their knowledge and inquiries. Our goal was to develop an environment where users of all ages and from all domains can collaborate and share in their knowledge construction efforts.

4. *Modular architecture*
   CmapTools was designed based on a modular architecture, in which components can be added or removed as needed from a Core module. This facilitates the development and evaluation of modules in a research environment without affecting other parts of the program. It also allows different ideas to be tested concurrently and independently, as well different versions of the program to be tailored to the needs of different users. On the server side, the various components are services that can be added or removed from the program, or started and stopped, as needed.

In the next sections we expand on the first three objectives listed above to describe CmapTools. Discussing the fourth objective is more technical and beyond the scope of this paper.

4 Low Threshold, High Ceiling

The user interface of CmapTools was designed to be nonintrusive, allowing the user to concentrate on the task of constructing the concept map without distractions. Figure 1 shows the canvas window on which the user builds (and browses) concept maps. The interface is model-less (e.g., there is no "concept" mode or "link" mode), and the map components (concepts, linking phrases, connecting lines) can be put together by direct clicks of the mouse on the canvas. This allows the user to concentrate on building the map as opposed to moving the mouse around to select boxes, lines, and so forth, as in drawing programs. Note the lack of intimidating collections of "icons" – we aim to provide a clean, simple interface. Style options (e.g., fonts, colors, curved lines, etc.) are provided via a style palette that can be hidden at any time. Constructing a simple map is straightforward, and new users are up and "mapping" after just a few minutes. At the other end, the style palette allows the creation of graphically more sophisticated maps, as is demonstrated by the concept maps that form the websites for both CmapTools itself (http://cmap.ihmc.us, e.g., Figure 1) and the CMC2004 conference (http://cmc.ihmc.us). At these websites images and colors are combined to provide visually more appealing designs while preserving the strong communication characteristics of concept maps.

The user interface and functionality of CmapTools was designed to be simple enough to be appropriate for children and naïve users without much technical expertise, but powerful enough to support the advanced needs of expert knowledge engineering users. As a result, thousands of users from over 150 countries are using it to construct knowledge models based on concept maps. They range from preschoolers in Italy (e.g., Giombini, 2004), to professionals in a variety of organizations who have applied CmapTools to a broad range of applications (Beirute & Barahona, 2004; Dumestre, 2004; Moon, 2004; Peacock, Schaffer, & Zelik, 2004).

5 Construction of Knowledge Models

CmapTools has a number of features intended to support the development and publication of collections of interlinked concept maps and associated resources. The program supports both the constructing and browsing aspects of publishing and navigating: At the same time it is the editor and the browser. Alan Kay, recipient of the 2004 Turing Award, "decries what he sees as a fundamental failing of the web—it is primarily an environment for displaying information, not for authoring it. 'You can read a document in Microsoft Word, and write a document in Microsoft Word. But the people who did web browsers I think were too lazy to do the authoring part.'" (Kirkpatrick, 2004) Tim Berners-Lee (2004) considered that "There are many parts of the original dream which are not yet implemented. For example, very few people have an easy, intuitive tool for putting their thoughts into hypertext." Although it could be argued that most people are more interested in searching for information than in creating it, this distinction has a potentially huge impact in the educational arena, where there is a gigantic difference pedagogically between students as knowledge constructors and students as information (web) consumers.

To show the relationships among concept maps in a set, CmapTools facilitates the linking of concept maps through simple drag-and-drop operations, enabling the navigation from one map to another. Additionally, the user can establish links to all types of resources (e.g., images, videos, sound clips, texts) that are related and complement the information in the map, and can reside anywhere on Internet. The links are depicted as icons underneath the concepts (or linking phrases). The icon itself portrays the type of resource targeted by the link, and labels are displayed explaining each link when the icon is clicked. Figure 2 shows several opened windows, the result of navigating through a knowledge model that includes possible landing site craters on Mars (Briggs et al., 2004). The "Mars (Root)" concept map is the top-level map, the entry point to this knowledge model. Some concepts in the "Mars" map have small icons underneath them. After clicking on the "concept map" icon underneath the "Space Missions since 1965" concept, from the list of concept maps displayed the user can select and open, for example, a "Space Missions" concept map (not displayed in Figure 2). The "Gusev Crater" map window in the figure was opened after navigating through several maps, starting at the concept "Space Exploration" (not shown) in the root map. The other images displayed were opened by similar navigation through the icons in the maps. Briggs et al. (2004) provided a detailed account of the construction of a large knowledge model that includes over 100 concept maps and over 600 MBs of resources. Using concept maps as a browser for navigation through a large domain has been found to be particularly effective, as discussed by Carnot et al. (2001).

CmapTools provides a rich collection of additional features that aid users in the manipulation of knowledge models. The Views window (see Figure 3) allows the user to create a hierarchy of folders in the user's computer or at a server to organize concept maps, images, videos, or URLs, all resources associated with a project. Through drag-and-drop operations, resources and knowledge models can be moved around or copied to servers (as explained in the next section), while links are preserved or updated. Among other features we cite: importing and/or exporting as images, web pages, outline, Topic Map format, XML, and so forth; recording for playback the steps in constructing a map; a full-screen presentation module; and a concept suggester that mines the web for relevant concepts (Cañas, Carvalho et al., 2004).

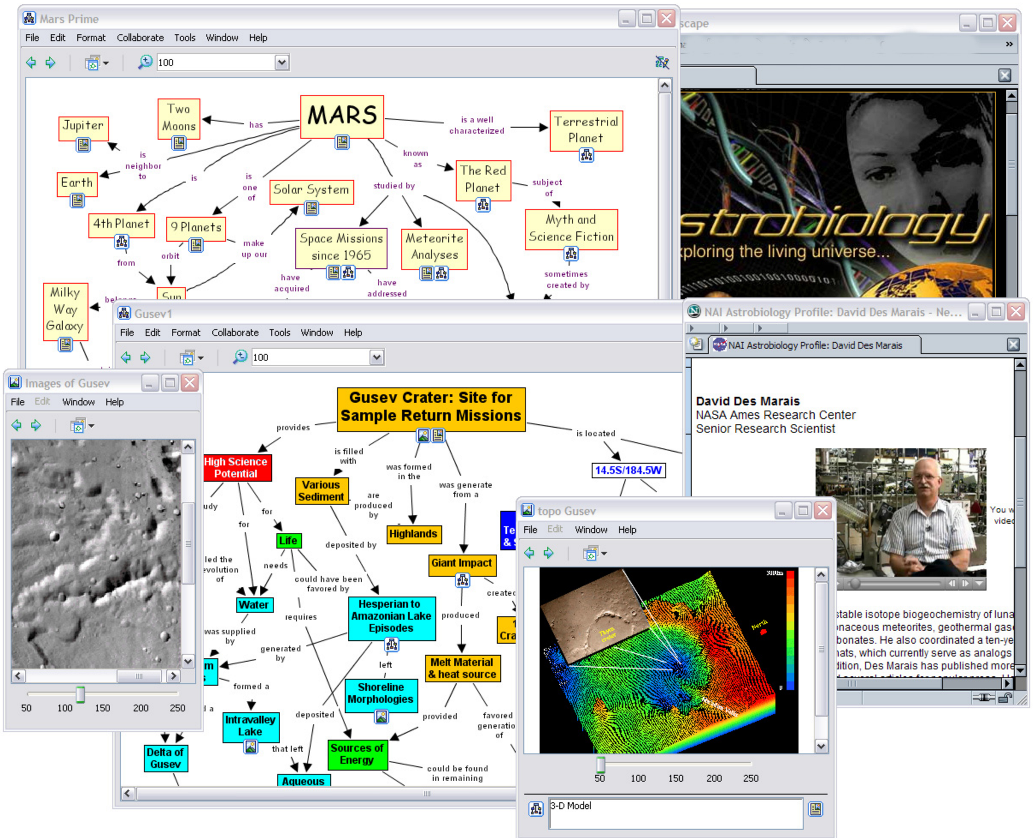

Figure 2. A knowledge model proposing the Gusev Crater as a possible landing site in Mars

6 Collaboration and Sharing

The CmapTools program works well as a stand-alone tool, allowing the user to construct concept map-based knowledge models and store them on his or her computer's hard drive, establish links among maps and to resources in the hard drive, and print the maps. However, the ease with which knowledge models can be shared, and collaboration can be established through shared Places, is what makes CmapTools unique. Physically, a Place is a server computer running the CmapServer software. From the user's perspective, a Place is a shared location, accessible through the Internet or an Intranet, where he/she can construct knowledge models collaboratively with colleagues or peers, where these knowledge models can be shared with others, and where he/she can access, browse, and comment on others' knowledge models.

The purpose of the CmapTools network is not limited to allowing users to share in the construction of their knowledge models. The network is designed to encourage and facilitate *public* sharing of knowledge. To achieve this, two key features were included in its design:

a) The CmapTools program must be able to automatically locate new Places that are installed in the network, so that new knowledge models are available to all users, and
b) Public Places must be available on the network so that anybody can publish and share their knowledge models, even if they are not associated with an organization that has a CmapServer.

To automatically locate new Places, every time the CmapTools program is launched it automatically contacts a Directory of Places: a special-purpose server with which Places register periodically (Cañas, Hill, Granados, Pérez, & Pérez, 2003). Figure 4 shows four Places (Public Cmaps, KM Cmaps, Science Cmaps, and History Cmaps) that periodically register with the Directory of Places, letting it know their network location and what services they can provide. It also shows a CmapTools user whose program has contacted the Directory of Places and thereby located the Places available. The CmapTools program continues contacting the Directory of Places periodically, making sure it is aware of any new Places that are made available. The window on the left of Figure 3 shows the list of Places available to a user at a particular point in time. Some of these Places appear

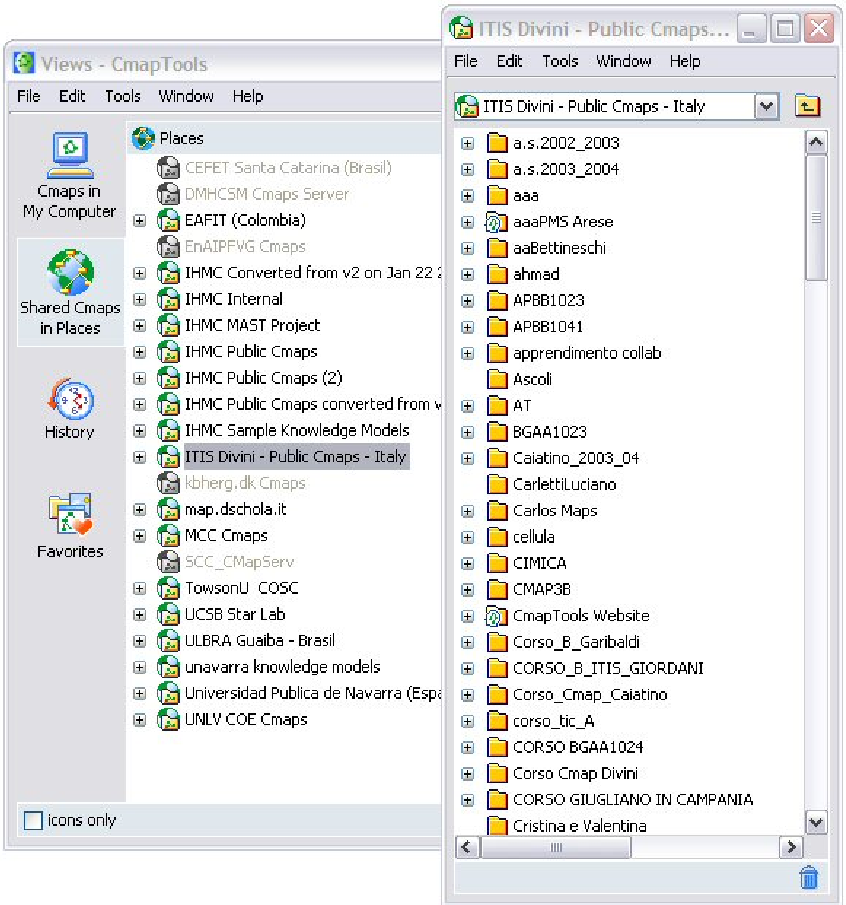

Figure 3. The Views window (left) showing available Places, and a partial view of the IT IS Divini Public Place in Italy (right).

grayed out, either because they may be behind a firewall or because CmapTools is aware that they were recently registered, but for some reason are not reachable at this moment. As new Places are installed on the network, the CmapTools program discovers them automatically and adds them to this list.

The Public Places are computers running the CmapServer program, configured in such a way that any user on the Internet can create his/her own folder, construct concept maps in it, copy knowledge models from his/her computer to it, and share that knowledge with others. Certain permissions are set on these Public Places such that *any* user on the Internet, without *any* prior authorization, is able to create a new folder. The permissions also make the user the *Administrator* of the folder and any subfolders that he/she creates under it. The user determines who has permission to read, modify, or annotate the resources in the folder (Cañas, Hill, Lott, & Suri, 2003). For example, the annotate permission allows a user to add comments (annotations or post-it notes) or discussion threads to concept maps in those folders, without having permission to modify or delete the maps. This way, a user can publish his/her concept maps and set permissions such that others can comment on them and provide feedback, without being able to modify the maps. This Public Places network, together with the permissions scheme, is particularly suited for peer review and collaborative projects where users, whether students or scientists, can easily share and collaborate in the construction of their knowledge models.

Collaboration through shared folders, annotations, and discussion threads is asynchronous: Users don't need to be working on the maps at the same time. CmapTools also supports synchronous collaboration: If two or more users located anywhere on the Internet attempt to edit the same concept map located at a Place, the system confirms with the users that they want to collaborate and begins a synchronous collaboration session. During this session, users can simultaneously modify the map, and changes are reflected on the screens of all participating users. Each modification made on the map is identified on the screen by the userID of the user performing it, and a chat window is available for text communication among participating users. Also asynchronously, users can collaborate at the 'knowledge level' through the Knowledge Soups described earlier in this paper.

The window on the left in Figure 3 has the Place "IT IS Divini – Public Cmaps – Italy" selected. Teachers and students of all ages from schools throughout Italy and from other countries take advantage of the public availability of this server to collaborate and share in their knowledge model construction. The window on the right shows a partial view of the folders available at the root level of that Place. The list of Places in the Figure also includes Public locations in Spain, Brazil, and Colombia. Thousands of users are sharing their knowledge models in these Public Places. As of June 2004, approximately 20,000 concept maps were being shared on these servers. Of course, additional maps are stored in the users' personal computers and Places that are not public.

The growing number of Places and the increasing number of concept maps and resources stored in them makes it impossible to "browse" through the folders for maps and information of interest. Each CmapServer keeps an index of the content of all concept maps and resources stored in it (and of web pages linked to by the concept maps), which makes searching through the Places easy and fast. In addition, all of these indexes are copied to an IndexServer, making searching through all servers just as easy. Users can also refine the search by indicating where to search, and what type of resources to search for.

CmapTools also offers the capability of searching the web for information that is relevant to a concept map. Users can select a concept within a map, and ask the system to search through the web for information relevant to the concept within the context of the map. The program takes advantage of the structure and semantics of concept maps to construct a query, send it to Google, rank the results, and present them to the user. (For more details, see Carvalho, Hewett, & Cañas, 2001; Leake et al., 2004).

The web is the best medium to offer information to the largest possible number of users. The objective of making knowledge models publicly available would be incomplete if the concept maps were not accessible on the Internet using a web browser. CmapTools facilitates publishing through the web by automatically converting concept maps saved on Places to HTML (web pages) that can be browsed immediately using an Internet web browser (e.g., Internet Explorer, Safari, Netscape). The concept map in Figure 1 has a URL at the bottom of the window that is the HTML version of the map's web address. The CmapServer includes a web server that delivers HTML versions of the concept maps it stores, and as such can support concept map-based websites. The concept maps in the CmapTools and CMC2004 websites (http://cmap.ihmc.us, http://cmc.ihmc.us) are all stored in CmapServers. Alternatively, the user can explicitly export a concept map or a knowledge model as web pages that can then be uploaded to a website for publication (Cañas, Carvajal, Carff, & Hill, 2004). Thus, any user can publish on the web the concept map-based representation of his/her understanding of a domain by constructing the concept maps in a Public Place, or constructing them in his/her computer and copying the maps to a Public Place.

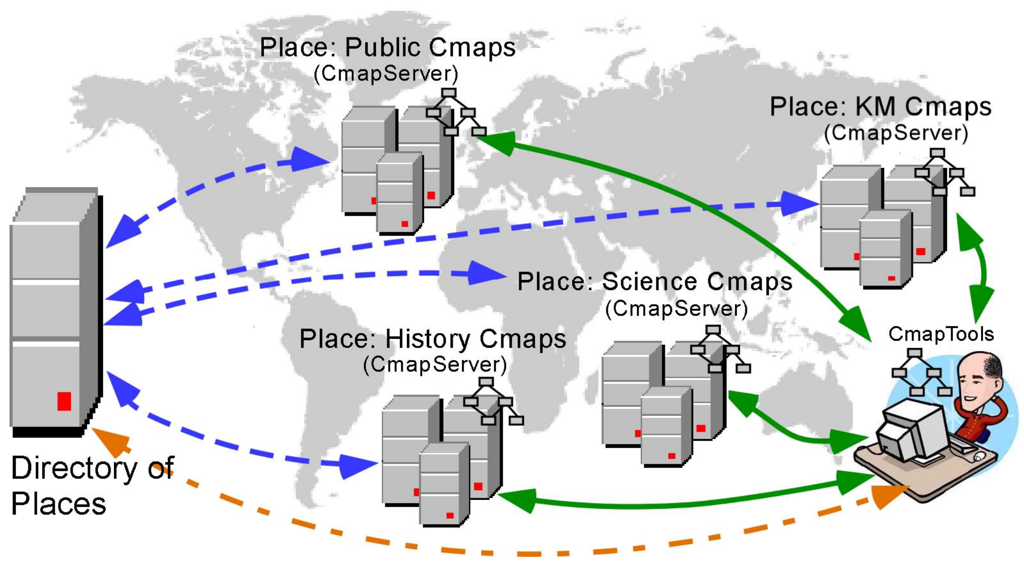

Figure 4. The CmapTools program locates Places that are registered with the Directory of Places.

7 Summary

The CmapTools software toolkit was designed to support constructing and sharing concept map-based knowledge models. Emphasis was placed on implementing a software program that is easy to learn, but powerful enough to support sophisticated uses. Based on lessons learned from previous research efforts, tools to enable the construction of concept map-based multimedia systems and strong support for collaboration are key components of the toolkit.

The software is available in many languages, and has enabled tens of thousands of users throughout the world to share and collaborate through a network of Public Places where any user, whether a student, a teacher, or a scientist, can create their own space and publish their knowledge models.

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MINING THE WEB TO SUGGEST CONCEPTS DURING CONCEPT MAP CONSTRUCTION

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Abstract. The most challenging aspect of constructing a concept map is not coming up with the list of concepts to include, but linking the concepts into meaningful propositions to create a coherent structure that reflects the person's understanding of a domain. We present an algorithm which, during the process of concept mapping, takes the partially constructed map as input to mine the Web, and presents to the user a list of suggested concepts that are relevant to the map under construction. We previously reported that testing an initial implementation of the algorithm with a set of users during a concept-mapping workshop seemed to support its viability. In this paper, we present the results of an experiment in which users rank the relevance of concepts suggested by the algorithm during a concept map construction session, using an implementation of the algorithm in the CmapTools software.

1 Introduction

Concept mapping is a process of meaning-making. It implies taking a list of concepts – concepts being perceived regularities in events or objects, or records of events or objects, designated by a label (Novak & Gowin, 1984) – and organizing them in a graphical representation in which pairs of concepts and their linking phrases form propositions. Hence, key to the construction of a concept map is the set of concepts on which it is based. In educational settings, teachers often prompt students by providing an initial set of concepts that they should include in their map.

Coming up with the list of concepts to include in a concept map is primarily an issue of retrieving from long-term memory. In fact, rote learners are particularly good at listing concepts for a domain. It is the process of linking the concepts to create meaningful propositions within the structure of a concept map that is the most difficult task. Jonassen (2000) emphasized that nontrivial effort may be required to choose a linking phrase that represents the relationship between two concepts, not only because of the large number of possibilities, but also because of the need to set that relationship in the context in which the pair of concepts is presented. However, the need to identify relevant concepts may require effort that distracts from the task of creating meaningful propositions.

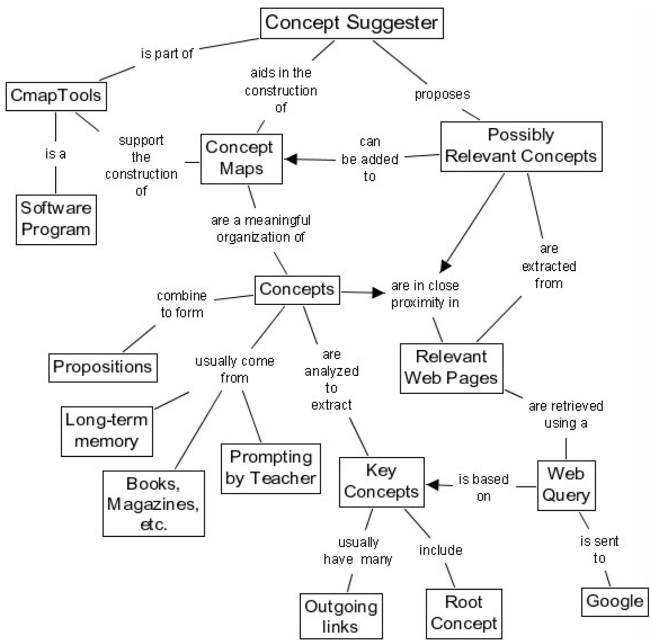

Figure 1: A concept map on the *concept suggester* module.

Often, while constructing a concept map, users – whether elementary school students, scientists, or other professionals – pause and wonder what additional concepts they should include in their map. It is not that they do not know more about the domain they are modeling, it is that they cannot "remember" what other concepts are relevant.

At the Institute for Human and Machine Cognition (IHMC) we have developed CmapTools (Cañas et al., 2004), a widely used software program that supports both the construction of concept maps and the annotation of the maps with additional material such as images, diagrams, video clips, and other such resources. It provides the capability to store and access concept maps on multiple servers and supports knowledge sharing across geographically distant sites.

In this paper we report on the usability of a *concept suggester* module, part of version 4 of CmapTools, which automatically analyzes a concept map under construction, extracts information from it, proactively searches on the World Wide Web (WWW) for concepts that may be relevant to the context of the map, and presents the user with a list of concepts as suggestions for possible inclusion in the map. Previously, we reported preliminary results (Cañas, Carvalho, & Arguedas, 2002) that lead to the development of the module and its inclusion in the software. This *concept suggester* module is part of a larger effort to aid users in the construction of concept maps. Leake et al. (2002) described a module that suggests prior concept maps and associated resources that the user can compare and possibly include as part of the concept map being constructed. Leake et al. (2004) presented a general framework on how to search the WWW using a concept map to generate the query.

This paper begins with a short description of concept mapping. It then presents an example of the use of the *suggester* followed by the algorithm used to extract relevant concepts from the WWW. Finally, results from an experiment in which users ranked the suggested concepts are presented and discussed. Figure 1 shows a concept map summarizing the purpose and function of the *concept suggester*.

2 Concept Maps and Concept Mapping

Concept maps are tools for organizing, representing, and sharing knowledge. Specifically, concept maps, developed by (Novak & Gowin, 1984), have been designed to tap into a person's cognitive structure and externalize concepts and propositions. A concept map is a two-dimensional representation of a set of concepts constructed so that the interrelationships among them are evident (see Figure 1). The vertical axis expresses a hierarchical framework for the concepts. More general, inclusive concepts are found at the highest levels, with progressively more specific, less inclusive concepts arranged below them. These maps emphasize the most general concepts by linking them to supporting ideas with propositions.

Concept maps are assimilation theory's major methodological tool. Ausubel's (Ausubel, 1968) assimilation theory belongs to the family of theories contributing to a constructivist model of human representational processes. Ausubel posited that meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures. This assimilation of new meaning leads to progressive differentiation and reintegration of cognitive structures. He explicated various forms of meaningful (as opposed to rote) learning involving the assimilation of new information. Ausubel assumed that meaningful learning requires that the learner's cognitive framework contain relevant anchoring ideas to which new material can be related. Indeed, he argued that the most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly.

Meaningful learning results when learners make a conscious effort to relate new knowledge to be learned with relevant knowledge they already possess. In contrast, rote learning results when learners memorize the new information and make little or no effort to relate and integrate this with their prior knowledge. Information learned by rote is notoriously soon forgotten, and there is little chance for the application of this knowledge in new problem solving contexts (Novak, 1998).

A growing body of research indicates that the use of concept maps can facilitate meaningful learning. During concept map construction, meaning-making occurs as the learner makes an effort to link the concepts to form propositions. The structure of these propositions in a map is a reflection of his/her understanding of the domain. Therefore, the meaning-making process involves both coming up with the list of concepts to include in a map and establishing the relationship between concepts. A rote learner may very well come up with the same list of concepts as a meaningful learner, but may not be able to establish explicitly the relationship between the concepts in the form of propositions. On the other hand, providing a meaningful learner with a richer set of concepts on which to build his/her map can help the learner construct a more complete representation of his/her understanding of the topic.

3 CmapTools and the Concept Suggester

Software programs like CmapTools make it easier for users to construct and share their knowledge models based on concept maps. In CmapTools we have extended the use of concept maps to serve as the browsing interface to a domain of knowledge, and have provided a tool that allows users to construct, organize, navigate, criticize, and share knowledge models. The software is widely used all over the world, by users who range from elementary school children, to professors creating content for distance learning courses, to NASA scientists. Applications of the tools range from supporting collaborative knowledge construction by students from different countries (Cañas et al., 2001), to just-in-time training (Coffey et al., 2003), to a large multimedia knowledge model about Mars at NASA (Briggs et al., 2004).

This broad range of users and applications has provided us with extensive feedback on the process of concept map construction. Taking advantage of this information, we have enhanced the tools with additional features to proactively aid the users in the construction of their knowledge models. Within this effort, we propose that unobtrusively presenting to the user a list of concepts that seem to be relevant within the context of the concept map being constructed, would allow users to concentrate on the meaning-making process of linking the concepts to form propositions and structuring the map, while freeing them from the effort of "remembering" which concepts are missing.

Consider the concept map about concept maps constructed by Joe Novak shown in Figure 2. Which other relevant concepts should be added to this map? The pane on the right shows what the *concept suggester* lists as possible concepts to add. (Figure 3 shows a larger version of this list.) These terms appear automatically as a user constructs the maps, and are updated when the program determines that the map has undergone significant changes. We have highlighted the term "Novak" in the list of suggestions. By analyzing the content of the map and searching through the Web, the *suggester* has determined that the term "Novak" is relevant to this map. Obviously, a relevant addition to the map would be to include that "concept maps were invented by Joe Novak," and the user may have forgotten to add it, although s/he was aware of it. (In this particular case, the authors are certain that Joe Novak was too modest to include it.) Other relevant concepts suggested in the list include "assessment," which is one of the main applications of concept maps, "study," "student," "science," and "understand (understanding)." Within the list, some suggestions may not make sense, for example, "reference"

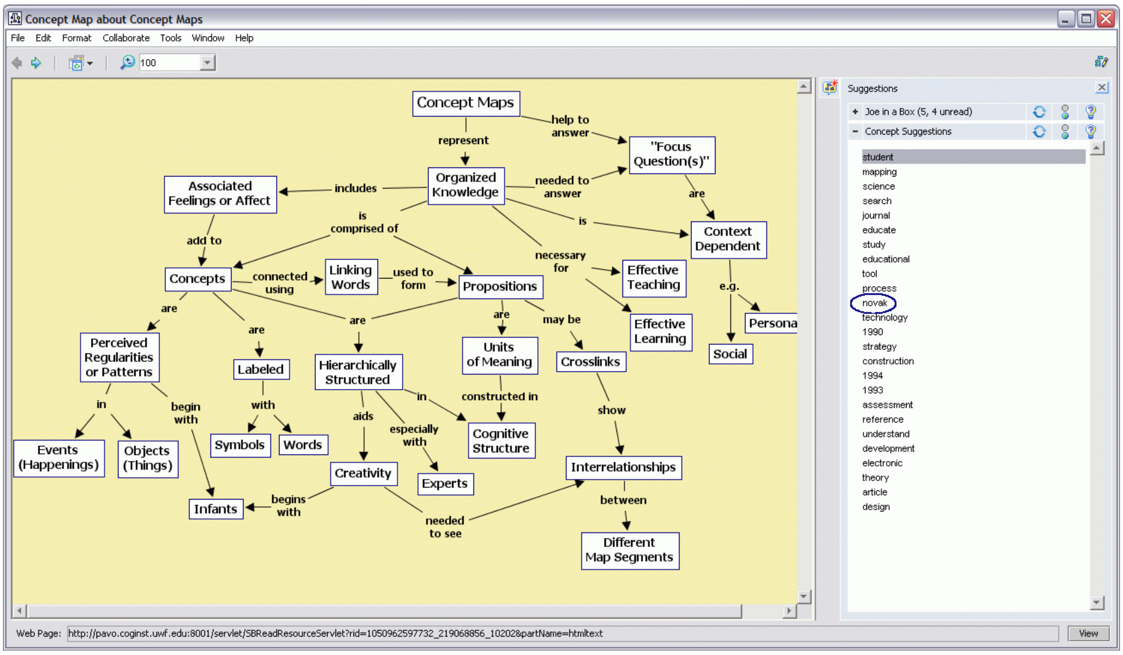

Figure 2: Concept map about concept maps by Joe Novak, and a list of suggested concepts from the CmapTools *concept suggester*.

and "article." The user can double-click on the suggestions to display Web pages that include the selected term within the context determined by the concept map.

We are aware that the *concept suggester* will not be able to come up with a list of terms that are all relevant to the map, given that all it is doing is mining the Web without any real understanding of the map itself. However, we believe that even if only two or three relevant concepts in the list trigger ideas in the user, it will result in an improved concept map.

4 The Concept Suggester

To find and suggest relevant concepts, we take advantage of various key characteristics of concept maps:

1. Concept maps have structure: By definition, more general concepts are presented at the top with more specific concepts at the bottom. Therefore, different weights can be assigned to the concepts in the partially constructed map according to their relative vertical position. Other structural information, for example, the number of ingoing and outgoing links of a concept, may provide additional information regarding a concept's role in the map. (Leake, Maguitman, & Reichherzer, 2004 presented experimental support for the cognitive importance of such factors.)

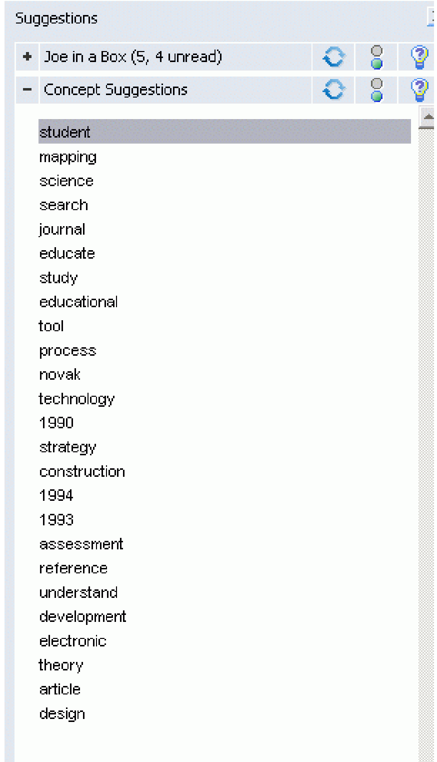

Figure 3: List of concepts suggested by CmapTools for the concept map about concept maps in Figure 2.

2. Concept maps are based on propositions: If two concepts form a proposition, the Web search for relevant documents may take into account that they are related, by seeking documents in which the two concepts appear related due to their proximity to each other in the text.

3. Concept maps have a context: A concept map is a representation of a person's understanding of a particular domain of knowledge. As such, all concepts and linking phrases are to be interpreted within that context, and the concept finder can take advantage of it.

As the user proceeds in the construction of the concept map, the program automatically reviews the changes as they are made and determines when it is appropriate to update the list of suggested concepts. The process of preparing a list of concepts consists of the following steps:

a) Analyzing the partial concept map to prepare a relevant query to use in searching the Web;
b) Retrieving relevant documents from the Web;
c) Extracting the relevant concepts from the retrieved Web pages;
d) Presenting the concepts to the user.

In this section, we describe the implementation of steps a) through c) of this algorithm in the CmapTools program. The system has undergone initial evaluation, and the results are described later in this paper.

4.1 Analyzing the Partial Concept Map

This phase consists of extracting from the concept map a limited set of words that represents the concept map's context, to be used as a query for our metasearch engine.

In traditional information retrieval, word frequency analysis is used to extract keywords from text. This approach, however, would not be effective in a concept map. The concise nature of the map would distort the frequency of words and, furthermore, because in a good map concepts are not repeated, all terms would most likely have the same frequency.

Our approach is to perform a graphical analysis of the partial map to identify the key concepts that play an important role in the context. Specifically, we try to identify concepts that refer to the focus question characterizing the topic of the map and concepts that are authority nodes.

Ideally, concepts consist of a single word, or a small set of words. In practice, though, during the process of building a map it is common to find concepts that consist of a large number of words, or even small phrases. For each concept, we try to identify the most relevant words by removing all stop words. If the result is still three words or longer, or if the result is an empty concept, it is discarded for the rest of the process.

At any stage of development, the root node of the map is usually a good representation of the overall topic of the map, or the focus question. The root node is assumed as an important concept, and its label is included as part of our query as long as it consists of less than three words once the stop words are removed.

Authority nodes are those with the highest number of outgoing links to other nodes. We assume that the outgoing links are indicative of further elaboration of these concepts, and therefore a gauge of their relevance in the context of the map. The algorithm selects, among all the nondiscarded concepts, those with the largest number of outgoing links. If more than one concept has the same (largest) number of outgoing links, they are all included in the query.

The process then consists of scanning the concept map to locate the root concept and the authority node(s). The overall number of concepts retrieved is dependent on the size of the map. Large maps might have many authority nodes, which would result in a larger number of key concepts. Given the restriction on concepts having less than three words, the process could yield an empty query, in which case the *suggester* cannot proceed. The query is constructed from the resulting concepts in no particular order.

4.2 Retrieving Relevant Documents

We use the query constructed from the key concepts in the previous step to retrieve and rank Web pages and build our collection of documents for the concept mining.

We have developed a metasearch engine, based primarily on Google (Brin & Lawrence, 1998), in order to retrieve an initial set of documents from the public Internet. The meta-search engine returns a small set of 10 to 20 URLs, depending on the query.

With the documents retrieved, parsed, filtered for stop words, and indexed, we proceed to the next phase, the actual mining for relevant concepts.

4.3 Extracting Relevant Concepts

Our current approach to extracting relevant concepts is simple: search all retrieved documents for all nondiscarded concepts from the map. Each time a concept is found in a document, all the neighboring words (excluding stop words) are saved in a temporary table. A word is considered a neighbor if it is part of same sentence as the concept in the text and is within a specific distance (currently three words) from the concept. In the current implementation, all neighboring words have an equivalent weight and are potential candidates for suggestion.

The result of searching for all of the map's concepts in all the documents is a large collection of terms that are neighbors of the map's concepts in the text. We now proceed to rank these terms using frequency analysis to obtain an ordered list of candidates for suggestion. This list is then part-of-speech (POS) tagged and sorted by frequency. The final set of concepts that is suggested to the user includes 15 concepts composed by the first five top ranking nouns in the sorted term list, followed by the top five verbs and the top five remaining terms. The *suggester* will automatically adjust these proportions as a function of the size of the subset of terms to display to the user.

5 Experimental Procedure

The experimental evaluation was based on human subjects ranking the relevance of proactively suggested concepts during the construction of a concept map. The goal was to determine the proportion of users that would find the suggestions useful during the map construction process.

Each participant received written and verbal instructions at the beginning of the experiment. The instructions described the goal of the experiment, the criteria for ranking suggestions, and details on how to use the *concept suggester* and assign relevance scores to the suggestions. The participants were also provided with a topic for a concept map and a version of CmapTools that was modified specifically for this experiment.

A single topic was proposed for all subjects. The participants were asked to build a single concept map about "Computers" with at least 20 linked concepts. During the map-building process, the *concept suggester* was running and proactively listing suggested concepts. At different times during the construction of the map, the participant was prompted to rank the displayed list of suggestions. At this time, s/he stopped the construction of the map and specified the relevance of each suggestion. Each suggested term was ranked on a scale from 1 to 5, where 1 meant "low relevance" and 5 "high relevance." Participants were instructed to assign higher relevance to suggested concepts that would satisfy the following:

a) The concept (or some variation of it) could be added to the map, or could be used as a replacement for a concept in the map in order to improve or extend its breadth (the user did not have to add the term to the map to rank it highly; we were interested in determining whether the user found the concept relevant).
b) The concept triggers a search for information that leads to the extension or improvement of the map.

On average, each participant was prompted at least five times for suggestions. At each instance, all the rankings were saved, together with the list of suggestions and the state of the map used to search the Web for suggestions. There were no constraints on time allotted for the construction of the map or for the ranking of suggestions.

After scoring all the suggested terms, the participant continued with the construction of the map. When the map reached 20 concepts, the experiment concluded. Figure 4 shows an illustration of the client application prompting the user for ranking.

During the experiment, the participants were allowed to request new concept suggestions at any time. In addition, CmapTools proactively generated new suggestions for users when significant changes in the concept map were detected. This is the normal behavior of the *concept suggester* within CmapTools. In both cases, however, at the appropriate time the user was prompted for ranking.

Fourteen participants volunteered for the experiment. The data from one of the participants had to be discarded because partly through the experiment it was determined that the instructions had been misunderstood

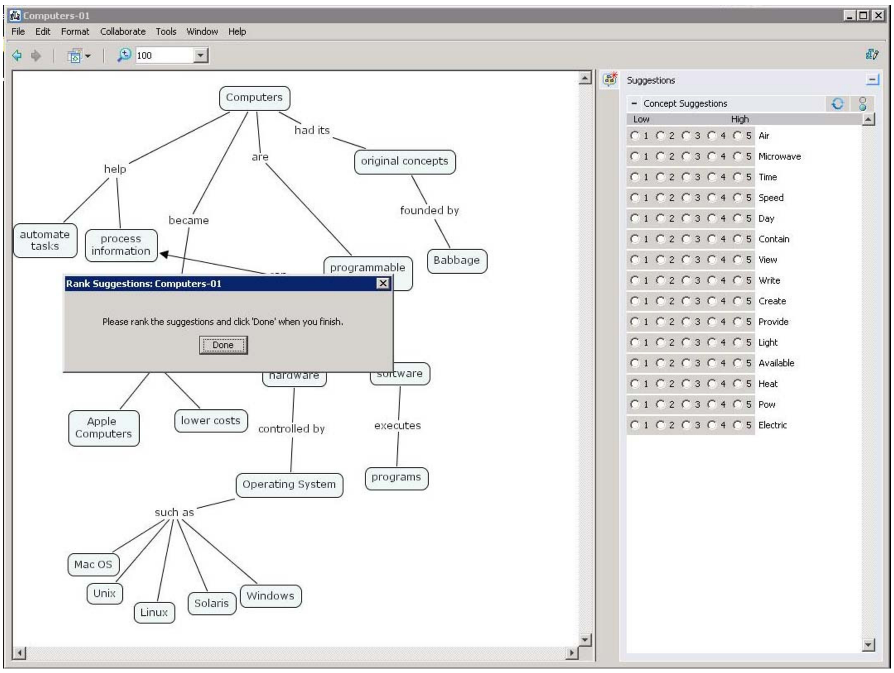

Figure 4: Prompting the user to rank the suggestions.

and the participant was ranking the suggested terms with respect to the selected concept in the map, not with respect to the whole map. All participants were familiar with the CmapTools application and with concept mapping although none of them had previous experience using the *concept suggester* during the construction of a map. The great majority of the participants (12 out of the 13 analyzed) had a computer science background, and all were familiar with the topic chosen for the map.

When the map reached 20 linked concepts, the subject was notified by the application that the experiment was over.

6 Experimental Results

We were interested in determining whether users reported that a *reasonable* number of suggested terms were *relevant*. To do this, we first established that a term was *relevant* if it was ranked 3 or above by the subject. Next, we determined a reasonable minimum number of relevant concepts at each stage. To do this, we considered that: (a) even a single relevant concept could have an important impact on the map construction, and (b) given the nature of the algorithm, in which suggested terms are mined from the Web, we could not expect most of the suggested terms to be relevant. We considered at least three or four relevant terms to be a reasonable criterion for a useful *suggester*. This number is subjective, of course.

Figure 5 shows the result of the experiment based on these two parameters. The chart on the left displays the percentage of subjects that ranked at least 4 concepts (out of the 15 concepts suggested) as relevant, for each of five stages in time while building the concept map. As can be seen, 85% (11 out of 13 subjects) considered at least 4 of the concepts suggested to be relevant when the map construction was at its early stages. This number decreased to 55% by the fifth ranking, however, as the construction of the map evolved. The chart on the right shows the percentage of subjects that ranked at least 3 concepts as relevant. In this case, the percentage decreased from 100% to 73%.

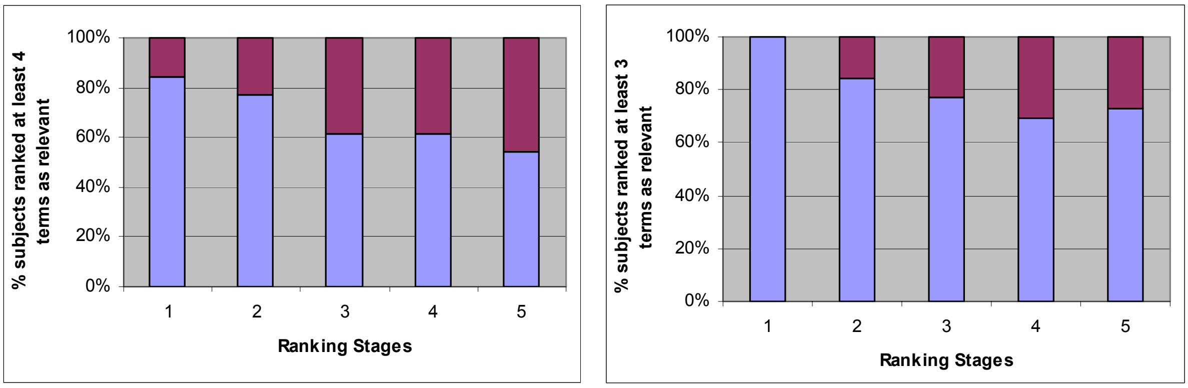

Figure 5: Percentage of subjects that ranked at least four (left) and at least three (right) suggested concepts as relevant in each of the ranking stages.

7 Discussion

The results show that the *suggester´s* algorithm is quite effective at the early stages of the construction of the concept map. Up to the third stage of ranking, the percentage of subjects that ranked at least four of the suggested terms as relevant was above 62%. Moreover, the percentage that ranked at least three as relevant was 77% or above. These numbers suggest that the algorithm is effective. However, in both cases we observe that as the concept map grows, the algorithm is less effective at finding relevant terms. The algorithm tries to determine "what the map is about." When the concept map is small, it is relatively easy to select the key concepts. As the map grows, the key concepts become spread throughout the map, making it more difficult for the algorithm to determine what the complete map is about. Also, as the map grows, the users tend to work on a piece or section of the map at a time. Consequently, for the concepts to be deemed relevant, they should be selected within the context of that piece of the map, not based on the map as a whole. Therefore, we propose that the algorithm be adjusted to take into account the dynamics of map construction.

8 Summary

Concept map construction is a meaning-making process in which listing the concepts to be included in the map is a less central task than selecting the appropriate linking phrase to form propositions. We have found, however, that users often struggle to "remember" new concepts to add to their maps when they should be concentrating their efforts on how to link those concepts to the map. We have implemented in the CmapTools software a proactive *concept suggester* module which, during map construction, analyzes the concept map, creates a relevant query to search the Web for documents related to the map, extracts relevant concepts from the retrieved Web pages, and presents the results as suggestions to the user. This module searches for new suggestions whenever it determines that the map has undergone significant changes. Tests of this module with a group of users suggest that it is effective in presenting relevant concepts to the users. This effectiveness diminishes as the map grows, however, which implies that the algorithm should be revised to take into account that in larger maps, users are most likely working on a piece of the map, and the suggested concepts should be determined by the context of that piece.

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ENTRE CONECTOR Y CONECTOR, UN PENSAMIENTO

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Abstract. Se describe y sistematiza la experiencia pedagógica ocurrida en el año 2003 con un grupo de 34 estudiantes de tercer año universitario, de la carrera de Educación Preescolar, en la Universidad de Costa Rica[1]. La experiencia se ubica específicamente en el curso "Artes del lenguaje II", cuyos ejes temáticos son el desarrollo del grafismo y lecto-escritura en niños y niñas en edad preescolar.
Los mapas conceptuales se han utilizado en el curso para sistematizar el aprendizaje, organizar estructuras conceptuales y repensar las propias ideas temáticas atinentes al curso. Esta estrategia ha compartido espacio con otra estrategia metodológica, los "diarios interactivos", que utilizan la "pregunta pedagógica" como estrategia paralela de reflexión. Sin embargo para el presente trabajo únicamente se presenta la sistematización en el uso de mapas conceptuales.

1 Introducción

No hay mejor práctica educativa que aquella que se hace coincidir con el discurso educativo. Mi reto profesional en las aulas universitarias ha sido precisamente el paso del discurso a la práctica de una manera congruente. Convencida de que el mejor ambiente para un docente en formación es el mismo que se desea para los niños y niñas con los cuales se trabajará, es que en el transcurso de dos décadas de docencia universitaria he desarrollado diversas experiencias metodológicas, sin embargo, el trabajo con Mapas conceptuales (MC) representa uno de los retos que mayor impacto ha provocado en mi persona, para llegar en comprender los estilos de aprendizaje en estudiantes universitarias. Además me permite afirmar que el aprendizaje significativo es válido para provocar efectos relevantes, tanto si se trabaja con niños y niñas de 3 años como si se trabaja con adultos.

Por tanto, a continuación se describe la experiencia desarrollada en el año 2003 con un grupo de 34 estudiantes de tercer año universitario, de la carrera de Educación Preescolar, en la Universidad de Costa Rica. Para lograr una mayor comprensión de la experiencia esta presentación se compone de siete aspectos:

- Contexto de la experiencia
- Premisas conceptuales para el uso de MC
- El seguimiento de un aprendizaje. Un procedimiento para MC
- Resultados cuantificables.
- Resultados cualitativos, lo no cuantificable.
- Lo que se concluye

2 Contexto de la Experiencia

El curso Artes del Lenguaje del Lenguaje II consta de 16 sesiones semanales y forma parte del plan de estudio de Educación Preescolar de la Universidad de Costa Rica. Entre sus propósitos, promueve el fortalecimiento de habilidades comunicativas y cognoscitivas que permitan un aprendizaje no sólo significativo, sino también relevante, aunado a una actitud de "responsabilidad ante el aprendizaje propio", de allí el uso de MC.

Como estrategia metodológica de base, los mapas conceptuales fueron utilizados paralelamente al uso de "diarios interactivos", los cuales se logró el fortalecimiento de otras capacidades: construcción de preguntas pedagógicas, justificación de opiniones, organización lineal de ideas. Por su parte el uso de mapas conceptuales funcionó como estrategia metacognoscitiva al "mapear ideas y conceptos relevantes para cada quien".

Las estudiantes debían elaborar semanalmente, en forma alterna, un mapa conceptual sobre la temática desarrollada y discutida en clase, teniendo como insumo una lectura previa. Esto dio como resultado siete entregas de Mapas conceptuales (MC) por parte de cada persona.

[1] La Universidad de Costa Rica, es una universidad pública, declarada institución benemérita, con 64 años de existencia en Costa Rica, Centroamérica.

En este artículo se pretende explicar y sustentar el uso real de mapas conceptuales como estrategia organizativa y constructiva del pensamiento y por tanto del aprendizaje. Valga señalar dos aspectos importantes:

- Las estudiantes habían experimentado el desarrollo de MC, aunque no de manera sostenida, si suficiente como para ser utilizados en un proceso de sistematización del aprendizaje en el curso de Artes del Lenguaje II.
- Como profesora universitaria ya había utilizado los Mapas conceptuales en éste y otros cursos, con este y otros grupos, experimentando diversas formas de uso, incluso con la herramienta informática del Cmap, versión 3.0. Sin embargo no es sino hasta el año 2003 que se consolida la estrategia de sistematización durante todo un curso.

3 Premisas conceptuales para el uso de MC

3.1 El mapa conceptual: herramienta de sistematización del aprendizaje

Ante la existencia de variadas herramientas para la concreción de diversos tipos de pensamiento, se hace necesario delimitar y justificar el uso de MC y no de otro tipo, como lo podría ser el mapa semántico.

Por una parte el mapa semántico, ofrece evidencia respecto al desarrollo léxico, ya sea básico o disponible[2] en un individuo. Por otra parte, el mapa cognitivo, según Boggino (1997) es una representación gráfica de una imagen mental y por tanto es singular e individual; se utiliza previamente a alguna intervención pedagógica intencionada (Boggino, 1997).

Según el mismo autor, los MC son de carácter social, responden al ámbito de una disciplina. Sin embargo desde mi perspectiva personal, el mapa conceptual, en la educación superior no puede abstraerse de utilizar como insumo las preconcepciones del estudiantado, por cuanto aquellas resultan de procesos e intervenciones anteriores, producidas en el ámbito científico y social de muy diversas disciplinas.

Para Novak (1998), el MC, corresponde a una herramienta que permite representar el conocimiento con aplicación en el marco escolar o empresarial, “son asimismo poderosas herramientas para facilitar el aprendizaje, así como instrumentos de evaluación” (Novak, 1998:30). En sí, los mapas conceptuales representan gráficamente las relaciones significativas entre conceptos que adquieren forma de proposiciones. Por tanto, para el curso en cuestión, los MC representan tanto las preconcepciones (lo cognitivo según Boggino) como las concepciones nuevas, de manera singular, entendiendo que la intención inmediata es provocar un aprendizaje significativo, que tenga efectos relevantes.

3.2 La versatilidad del pensamiento adulto. El pensamiento de lo general a lo particular, de lo particular a lo general.

Desde el punto de vista psicológico el desarrollo del pensamiento en el ser humano ocurre de lo general a lo particular. El infante generaliza visualmente su entorno: todos los animales de cuatro patas son “perros o vacas”; todas las imágenes de mujeres son “mamá”, en este caso el vocablo asume una generalidad utilizada para el sexo femenino. Sólo cuando se percata de las particularidades es que logra identificar un animal de otro, una persona de otra.

El pensamiento adulto trasciende la posibilidad de mantenerse en lo general para llegar a lo particular con mucha más fluidez. Esta es la base para llegar a lo que he dado en llamar “pensamiento versátil”, el cual se caracteriza por:

- Fluir entre la verticalidad y horizontalidad. Verticalidad para ir de lo general a lo particular, esto es, de arriba hacia abajo, pero también de abajo hacia arriba. Horizontal, por cuanto se produce conectividad entre aspectos diferentes.
- Ser holístico, al ser mediatizado por el contexto cultural, las propias creencias, las de otros, así como la propia capacidad creativa y de asombro.
- Ser abierto, tolerante y prudente: al permitir nuevas creaciones y considerar nuevas ideas sin desestimar irreflexivamente lo ya consolidado.

[2] Dentro de la lingüística, especialmente dentro del campo de la lexicografía se entiende por léxico básico, aquel que utiliza cotidianamente y léxico disponible es aquel que aunque no se use forma parte del vagaje mental del individuo.

Ahora bien, esta capacidad para pensar versátilmente no siempre se produce de manera eficiente, por cuanto a nivel de Educación Superior nos encontramos con procesos cognoscitivos básicos que aún deben atenderse. Es por tanto, función de los entornos educativos formales, permitir que esta capacidad se desarrolle y se mantenga, permitiendo que crezca según las posibilidades individuales. Un estudiante universitario debe y tiene la posibilidad de utilizar un "pensamiento versátil".

3.3 El aprendizaje significativo y el efecto relevante

El concepto de aprendizaje significativo ha sido altamente analizado por el Dr. Novak y otros autores como marco de sustento en el uso de MC. Por tanto no se acotan aquí nuevas ideas en este sentido, sino más bien reafirmar lo ya propuesto por Ausubel. Sin embargo valga la pena prestar atención al concepto de relevancia y su aplicabilidad en el aprendizaje.

Desde el punto de vista de la comunicación, *"Un supuesto es relevante en un contexto si y sólo si tiene algún efecto contextual en dicho contexto*" (Speber y Wilson, 1994:153). Dado que la relevancia es un asunto de grado, ese efecto (producto de procesos mentales) dentro del contexto debe ser grande, por tanto, agregan los autores, existe de alguna manera, alguna conexión entre supuesto y contexto. Los autores desarrollan su teoría agregando los factores que inciden dentro de la comunicación relevante y destacan el factor de esfuerzo de procesamiento como un elemento fundamental. De esta manera un supuesto es relevante cuando el efecto contextual es grande y el esfuerzo ha sido pequeño.

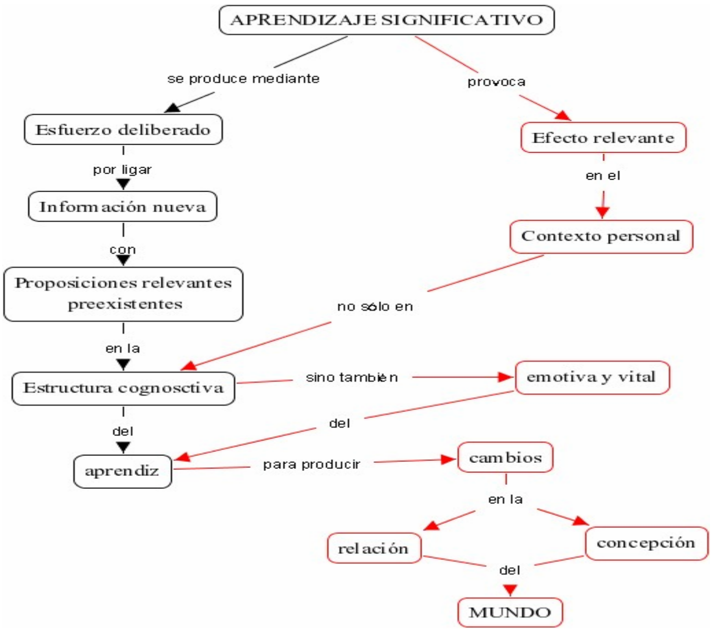

Figura 1. Aprendizaje significativo efecto relevante..

Dado que estas premisas son dadas dentro del marco de una teoría de la comunicación, resulta relevante, valga la redundancia, dentro del ámbito del aprendizaje, por cuanto éste es el resultado de una constante comunicación entre personas y el entorno.

La utilización de MC dentro del curso, si bien tiene como propósito lograr aprendizajes significativos, la meta es que esos aprendizajes alcancen efectos relevantes, es decir un efecto en el contexto no sólo mental, sino también emocional y vital del grupo de estudiantes. En el campo de la educación un aprendizaje cobra sentido cuando el efecto se produce no sólo para el individuo en sí mismo, sino cuando el efecto trasciende hacia el contexto, al producirse cambios en la manera de relacionarse y concebir el mundo. Ver figura 1

3.4 La responsabilidad en el propio proceso de aprendizaje

La responsabilidad como valor o como actitud lleva a la persona a tomar las decisiones de lo que hará o dejará de hacer respecto a su comportamiento ético o moral. Bajo este referente, la "responsabilidad en el propio proceso de aprendizaje" no es más que el tomarse en forma consciente, la responsabilidad del acto creador del pensamiento, tomar las decisiones de lo "que" se desea que fluya y las "formas" en que fluya o se manifieste. Necesariamente el uso de mapas conceptuales remite a una concepción constructiva del aprendizaje, donde el sujeto manipula, explora, descubre, inventa en un esfuerzo por reconstruir o crear (Según Cooll, en Díaz Barriga y Hernández, 2000). Para el mismo autor la función del docente está no sólo en crear las condiciones óptimas, sino en orientar y guiar explícitamente la actividad mental constructiva.

4 El seguimiento de un aprendizaje: un procedimiento para mapas conceptuales

Como ya se indicó, la utilización de MC se alternó con "diarios interactivos". Durante 16 semanas las estudiantes, debían contar con 7 entregas de Mapas conceptuales y 8 diarios interactivos. La producción era alterna, para una sesión se producía MC y para la siguiente un "diario interactivo" con preguntas pedagógicas elaborados por el mismo grupo o propuestas por mi parte. La producción se daba en sus casas, para ser entregados en la sesión siguiente. Para el presente trabajo se estará haciendo énfasis en la utilización de MC, cuyo procedimiento metodológico fue siguiente:

a. Cada quince días se entregaba un MC, acompañado de un listado de conceptos seleccionados, que sistematizaba la temática abordada en la sesión anterior. De esta manera se establecieron los siguientes temas, para siete entregas:

1. Conceptos de lectura y escritura. Nombre propio
2. Actos lectores y escritores. Concepciones de lectura y escritura en los niños y niñas.
3. Enfoque dialéctico de la comunicación. Desarrollo del Lector Independiente.
4. Aprestamiento. Tipos de letra "script" y cursiva, su uso.
5. Nociones integrales en la etapa preescolar (psicomotricidad y percepción)
6. Aportes de Nora R. de Chacón a la educación.
7. Ambiente letrado y centro de lenguaje.

La entrega número 6 es considerada dentro de los resultados por cuanto se tenía la opción de hacer un ensayo o un mapa conceptual. Aproximadamente la mitad optó por un ensayo u otro tipo de presentación.

Los mapas se elaboraban por elección propia en diversos formatos:

- A mano: 20 personas, con la variedad y estilo que cada quien quiso dar.
- En programa CmapTools (Cañas et al., 2004): 6 personas Ej. Figura 2.
- En programa Word: 7 personas
- En programa Excel: 1 persona

b. A la semana siguiente, los mapas eran devueltos a las estudiantes, con observaciones referidas a: aspectos poco claros, utilización de enlaces y conceptos, organización de lo general a lo particular, relaciones entre aspectos, interrogantes para ampliar las temáticas abordadas o establecer claridad en ciertos aspectos.

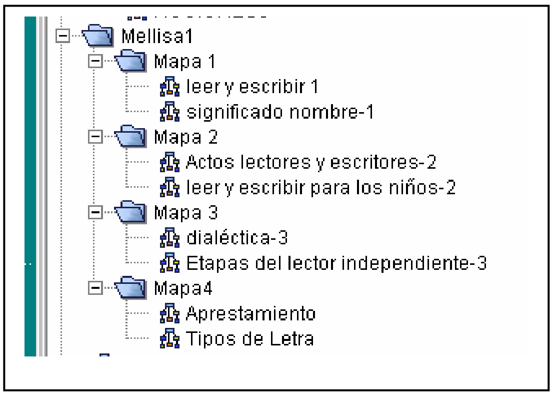

Figura 2. Ordenamiento de entrega final de MC en formato CmapTools.

c. Al finalizar la clase, se prestaba atención individual para escuchar explicaciones y ofrecer sugerencias.

d. Las estudiantes devolvían sus mapas ocho días después, atendiendo a las observaciones planteadas por la profesora, así hasta tres veces con un mapa. Para algunas la primera entrega fue suficiente, otras realizaron devoluciones en 2 o 3 oportunidades. A la tercera entrega como máximo se obtenía el porcentaje de entrega del mapa. Es necesario aclarar que los mapas por sí no tenían calificación numérica, la valoración se dio en términos de entrega y esfuerzo coherente para mejorar el mapa.

e. Atención individualizada: fue necesario atender a algunas personas de manera tutorial para trabajar aspectos tales como: diferenciación entre enlaces y conceptos, organización de lo general a lo particular, relaciones horizontales, confusiones conceptuales.

5 Resultados cuantificables

Estos resultados responden a un análisis basado en el registro evaluativo del curso, el cual se realizó en formato EXCEL, donde se establecieron diversos aspectos tales como: lista total de estudiantes, secuencia de entrega de los mapas, si la entrega fue completa o parcial, si se efectuaron mejorías (devoluciones), los temas de los mapas, cantidad de mapas entregados, entre otros aspectos.

Ahora bien, del análisis de estos aspectos se logran extraer cuantitativamente resultados en tres categorías: la primera se refiere a la presentación de mapas y sus devoluciones; la segunda se refiere al desempeño personal en términos de cantidad de mapas entregados y atención a las observaciones realizadas por la profesora; la tercera categoría se refiere al interés demostrado. A continuación se presentan esos resultados:

En la tabla l se observa que el grupo en general responde a la estrategia de elaboración y entrega de Mapas conceptuales. Únicamente en la quinta entrega seis personas omiten la entrega, sin embargo esto es atribuible a la coincidencia de entrega de trabajos de otros cursos, en el mismo período.

Secuencia de entregas / **Cantidad de entregas y devoluciones**	**Primera entrega:** dos mapas	**Segunda entrega:** dos mapas	**Tercera entrega:** dos mapas	**Cuarta entrega**	**Quinta entrega**	**Sexta entrega**
Cantidad de Mapas conceptuales entregados a la profesora:						
- Sin entregar	1	1	1	3	6	1
- Entregados	33	33	33	30	28	33
- Entregas parciales: de dos mapas se presentó solo uno.	2	2	2	-	1 (obvió una parte)	-
Cantidad de mapas devueltos a las estudiantes con observaciones	10	12	23	22	23	5
Cantidad de mapas mejorados que se regresaron a la profesora	5	9	19	18	17	Este úlitmo se regresaba.

Tabla 1: Presentación de mapas y devoluciones

En la tabla 2, se observa un desempeño general muy satisfactorio, por cuanto la mayoría de las estudiantes entregaron todos los mapas y los mejoraron. La excepción se da con dos estudiantes que no hicieron dos mapas.

Presentación (entrega a la profesora) de los mapas en términos generales	**No. de estudiantes**
- Presentaron todos los mapas	22
- Presentaron 4 o más mapas	10
- Presentaron menos de 3 mapas	2
Observaciones efectuadas por la profesora	
- Nunca tuvieron observaciones	0
- Tuvieron observaciones en 3 o más ocasiones	34
Mejoras efectuadas por las estudiantes en una segunda o tercera devolución	
- Mejoraron los mapas en todas las ocasiones	15
- Mejoraron los mapas al menos en 4 o más ocasiones	12
- Mejoraron los mapas en 3 o menos ocasiones	3
- Nunca regresaron los mapas, por tanto nunca mejoraron sus producciones.	4

Tabla 2: Desempeño personal

Respecto al interés demostrado, tal y como se observa en el la tabla 3, la mayoría de las estudiantes mostró un alto nivel de interés, resaltan en este aspecto las dos estudiantes que siempre estuvieron muy presentes en su propio proceso, exigiendo por parte de la profesora una mayor atención.

Actitud de mayor interés	**No. Estudiantes**
- Atendieron el llamado de la profesora para ser atendidas en sesiones extra, para el mejoramiento de los mapas	11
- Interesadas en recibir explicaciones generales después de clase	8
- Solicitaron por propia cuenta, atención constante a la profesora en sesiones extraclase	2
- Nunca fueron llamadas y nunca demandaron atención, sus producciones eran satisfactorias.	4
Actitud de menor interés	
- Nunca atendieron el llamado de la profesora, ni mejoraron sus mapas	4
- A pesar de las observaciones no mostraron interés en demandar explicaciones de la profesora. En algunos casos lograron una mejoría y en otros no.	5
TOTAL	34

Tabla 3 Interés demostrado

Por otra parte, aquellas estudiantes que mostraron menor interés fueron 9, entre ellas destacan 4 estudiantes que podrían calificarse con una actitud de indiferencia, al no atender el llamado de la profesora, dos de ellas intentaron buscar un espacio pero se disculparon por no contar con tiempo adicional para ser atendidas, otra de ellas al interrogársele indicó que el curso no la había motivado.

6 Resultados cualitativos, lo no cuantificable:

Estos resultados se dan como producto del seguimiento mediante la observación y el trabajo directo con las estudiantes, tanto individual como grupal. Son resultados cualitativos que se ofrecen en dos categorías: los estilos aprendizajes al descubierto, lo exitoso; y los inconvenientes ¿o procesos?, su abordaje.

6.1 Los estilos de aprendizajes al descubierto. Lo exitoso

Según el procedimiento descrito se revisaron alrededor de 285 Mapas conceptuales, en seis entregas. Esto dio la oportunidad para:

- Conocer diferentes estilos de abordaje al conocimiento. Seguimiento al desarrollo intelectual-afectivo de las estudiantes.
- Desarrollo de capacidades de síntesis. Recuérdese que la síntesis es la capacidad de recrear un hecho o situación desde la perspectiva personal, no de un autor. De esta manera el MC ofreció la posibilidad de abordar los conocimientos desde la perspectiva personal, aunque no totalmente individualizada, puesto que la dinámica de aula y el trabajo tutorial en pequeños grupos ofreció la posibilidad de presentar diversos puntos de vista respecto a las temáticas.
- Desarrollo de capacidades metacognoscitivas, por cuanto las estudiantes, en buen número valoraban sus propios estilos y formas de aprendizaje, así como sus propias creaciones. Por tanto, también se desarrollaron capacidades evaluativas respecto a sí mismas, en unas personas en mayor grado que en otras.
- Manejo de herramientas informáticas, por cuanto 14 personas las utilizaron.
- Al utilizar formatos diferentes para la elaboración de los mapas, se brindó espacio para la manifestación de diversos estilos de aprendizaje que mostraron las diferentes formas para establecer conexiones entre conceptos y resolver asuntos de ligamen.
  Un ejemplo de MC realizado a mano es la figura 4; un ejemplo de MC realizado en CmapTools es la figura 5 y un ejemplo de MC realizado en **word** es la figura 6. La persona que utilizó EXCEL resultó ser un caso particularmente interesante por cuanto podría pensarse que éste no es un programa apto para la elaboración de mapas y aunque ciertamente es menos fluido que otros, la estudiante logró un dominio tal que le permitió realizar producciones sumamente claras, organizadas y detalladas. En las figuras 7 y 8 se muestra un ejemplo del trabajo realizado por esta estudiante, quien hizo una propuesta global con 14 mapas conceptuales, todos enlazados mediante hipervínculos.
  Ahora bien, los estilos más notorios

Ahora bien, los estilos más notorios de aprendizajes se dieron en el campo de la propia organización del pensamiento, esto es, el desarrollo del pensamiento analítico. Se evidenciaron tres estilos, que van del más simple al más complejo:

Figura 4. MC. Elaborado a mano. Mileydy O.

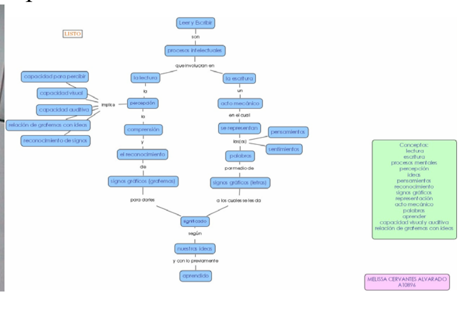

Figura 5. MC. Elaborado en CmapTools. Mellissa C.

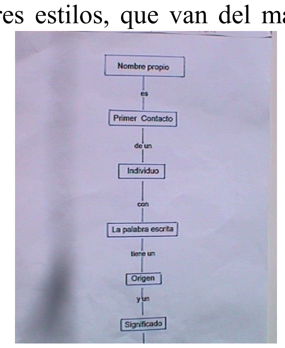

Figura 6. MC. Elaborado en Word.. Elvita T.

a. Entre los estilos más simples estaba el de conectar únicamente conceptos lo que dio como resultado muchos mapas aislados. Este estilo se dio sobretodo al inicio de la experiencia, algunas lo mantuvieron.

b. Entre los estilos más complejos se dio el de relacionar ideas o aspectos. Este estilo lo evidenciaron algunas desde el principio, o se presentó como producto del proceso, lo que dio como consecuencia un cantidad de mapas coincidente con el número de entregas. Sin tener número exactos, se puede afirmar que la mayoría de las estudiantes se ubicó en este nivel.

c. Este fue el nivel más complejo pues involucró los dos anteriores, agregando la relación entre mapas para lograr ver el contenido del curso como un todo. Este fue el caso de dos estudiantes, una de ellas, la que utilizó EXCEL, quien logró gran claridad en los tres niveles (fig. 7 y 8). Esta estudiante elaboró 14 mapas, cuyo origen fue un mapa general a partir del cual ligó los demás, manteniendo un orden de lo general a lo particular.

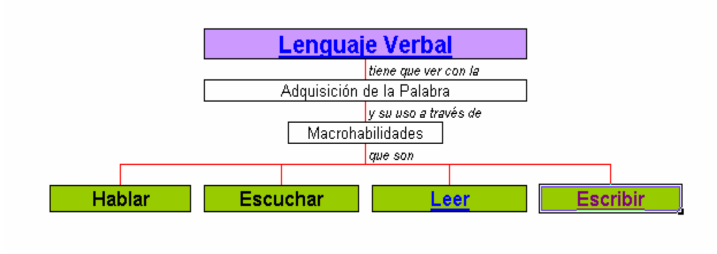

Figura 7. MC elaborado en EXCEL por Silvia N. (2003)

La otra estudiante trató de hacer un solo mapa (figura 9), sin embargo esto le evidenció dificultad para poder controlar un hilo conductor de lo general a lo particular, además de que el programa CmapTools le resultó insuficiente, por lo cual al final concretó 3 mapas ligados. A pesar de este logro evidenció dificultad en los dos primeros niveles: conexión entre conceptos (dificultad para discriminar conceptos de conectores) y dificultad para conectar ideas o aspectos. A pesar de lo anterior siempre manifestó interés y expresó sentirse "apasionada" por el trabajo realizado, puesto que le permitía visualizar la organización de su pensamiento. Una suposición que daría respuesta a la dificultad mostrada por esta estudiante es que su lengua materna no fue el español sino el inglés y que su abordaje del español estuvo contaminado por el inglés, nunca logró un dominio satisfactorio de la gramática española, en ocasiones se le escucha hablar mitad inglés, mitad español.

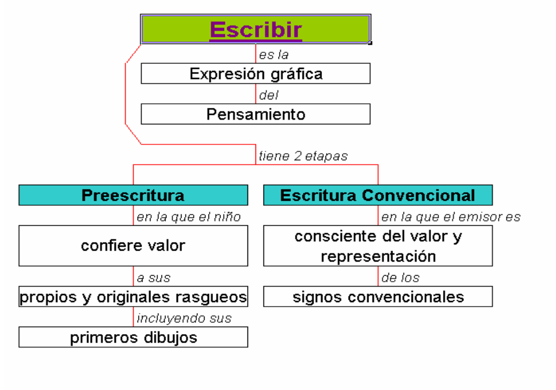

Figura 8. MC elaborado en EXCEL, por Silvia N. (2003)

- En términos de evaluación: la valoración se asume bajo dos líneas: valoración del esfuerzo, el proceso y no del resultado mismo. La valoración respecto a la competencia hacia sí mismo y no en competencia respecto a los demás. Se afirma esto por cuanto la valoración estaba centrada en la entrega y no en el resultado, al devolver un mapa a una estudiante, la intención era que se esforzara un poco y lograra algún nivel de mejoría respecto al mapa original, si esto ocurría se valoraba la entrega respecto al logro de una mejoría. Esta situación permitió respetar la individualidad cognitiva de cada quien. Únicamente en dos casos (dos mapas) la segunda devolución no mostró evolución, por lo que el valor porcentual de la entrega para esos dos mapas no fue alcanzado.

6.2 Inconvenientes ¿o procesos? y su abordaje

Durante el proceso se presentaron algunas dificultades, que podrían considerarse más bien como parte del proceso mismo:

- Confusiones respecto a la diferencia entre "concepto" y "enlace" (o conector). Para remediar esta situación se utilizaron carteles con conceptos y enlaces, para luego clasificarlos.
- Dificultad para determinar conceptos generales y conceptos particulares. Para esta situación se utilizó la clasificación de conceptos (escritos en carteles) y el ordenamiento de los mismos, de lo más general a lo más particular, pero a su vez una clasificación horizontal, según aspectos.

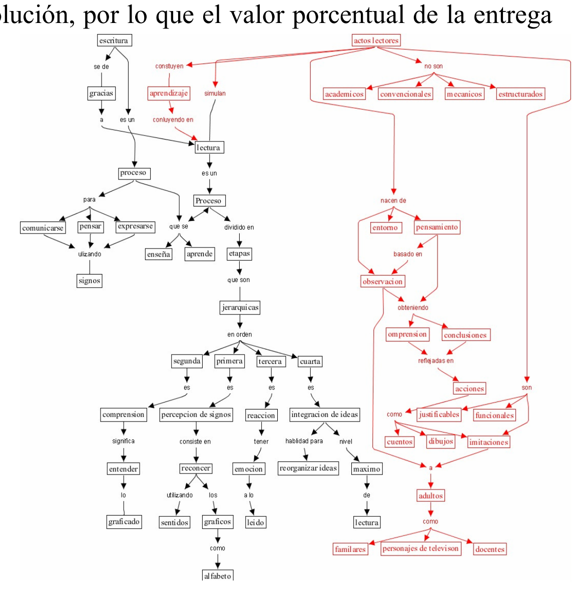

Figura 9 MC elaborado en EXCEL por Lidia C. (2003)

- Dependencia respecto a lo leído. Inicialmente algunas estudiantes concebían los mapas dependiendo de las lecturas previas y por tanto los elaboraban siguiendo la linealidad de los textos, obviando los aportes dados en la clase, según la discusión general del grupo y el aporte de la profesora. Para atender a esta situación, se solicitaba subrayar los conceptos relevantes, escribirlos en lista aparte, para luego apartar el texto inicial. Al listado en cuestión se incorporaban otros, surgidos de la dinámica de clase.
- Miedo al error. El temor manifiesto, mediante preguntas como ¿está bien o está mal?, ¿seleccioné los conceptos que había que seleccionar?. El abordaje más importante se dio en el sentido de no valorar cuantificablemente los mapas en sí. No calificar como bueno o malo, sino utilizar ideas descriptivas sobre lo que se podría mejorar, descripciones como "hay ideas inconclusas poco claras", "relaciones entre conceptos poco evidentes", "organización poco clara", "conectores no precisos o ausencia de conectores"; además la formulación de preguntas para recordar al estudiante otros aspectos que tal vez estaría olvidando o que harían de la producción algo más coherente. Pero finalmente la posibilidad de "recrear" los mapas fue lo que dio importancia a lo importante, el proceso.

Estas estrategias a su vez se desarrollaron en sesiones individuales y de pequeños grupos, en horas a convenir con las estudiantes. Esto trajo consigo un inconveniente en cuanto a la demanda de tiempo para mi persona como profesora del curso, sin embargo, por otra parte ofreció la oportunidad de dar seguimiento al desarrollo intelectual-afectivo de las estudiantes.

7 Lo que se concluye

La utilización de Mapas conceptuales posibilita el pensamiento versátil, por cuanto por su misma estructura y forma de construcción permite el establecimiento de diversas conexiones.

También propicia efectos relevantes, por cuanto se seleccionan ideas y se organizan de manera particular, según experiencias previas, lo que se cree y se siente. Se hace uso del pensamiento individualizado y colectivo. La decisión de lo que fluye y la forma en que fluye es una decisión personal, es responsabilidad "cognoscitiva". Finalmente es una manifestación personal. Adicionalmente los mapas conceptuales permiten una valoración del aprendizaje en términos más equitativos, de respeto a cada persona.

Ahora bien, desde el punto de vista de pensamiento como acto creador, los Mapas conceptuales representan una forma de manifestación de ese acto creador, una buena forma de manifestación, sin embargo no debe convertirse en "la forma" por cuanto muchas habilidades personales deben tener cabida en proceso educativo del ser humano, para llegar realmente a un entorno que promueva personas mayormente creativas.

A pesar de los logros se hace necesario tener presente que para iniciar la construcción de Mapas conceptuales es necesario que los estudiantes tengan:

- Claridad en la diferencia entre conceptos y conectores.
- Capacidad para identificar conceptos generales y particulares.
- Claridad en cuanto al uso de "proposiciones" o "afirmaciones".
- Claridad en el papel mediador del docente.

Como estrategia para la sistematización del aprendizaje y como herramienta evaluativa constituyen en la formación de docentes una metodología significativa.

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networks of concepts or Concept Maps. Novak (1998) described knowledge elicitation as a means of idea generation in groups of people.

Concept Maps have been used in institutional memory preservation work (Coffey & Hoffman, 2002). In work at NASA Glenn Research Center, Concept Maps were used in order to capture, represent, and preserve institutional memory of senior scientists on issues pertaining to launch vehicle systems integration (Coffey, 1999). The Centaur upper stage and the RL-10 engine were chosen for detailed analysis in this study. Six engineers, all of whom were at or near retirement from NASA or NASA contractors, were involved in this project. The result of the effort was a knowledge model organized around Concept Maps that was used in training.

The literature on concept mapping for KE contains studies involving one-on-one sessions with a single elicitor and single expert, several interviewers working with a single expert, several elicitors with several experts, etc. Studies have described uses that were prospective, retrospective, at a global strategic level and at a highly detailed level. The current case study, described in the next section, describes the use of Concept Mapping at a lower, technical level with one expert and two elicitors.

3 The Case Study

Since this was a pilot study, a relatively small undertaking was planned involving three experts. Due to space constraints, this article contains a description of KE work performed with one of them, an expert on air effluent analysis. The experts for this study were chosen by plant management based on a survey of employees who hold critical positions and are either currently, or will shortly become, eligible for retirement. This survey resulted in a two-page document that identified the critical areas of expertise for each expert. In order to prepare for the pilot study, IHMC personnel were given the assessments from which a set of questions were generated and answered by plant personnel before the first trip. Although preparations could have been deeper and more comprehensive, this advance work proved to be critically important given the limited amount of time with the expert. IHMC personnel went into the endeavor already familiar with ideas such as counting room, Offsite Dose Calculation Manual (ODCM), gamma and beta counting, etc.

The amount of time allocated for contact with the experts was based upon the number of hours of contact time that the budget for the work could support. The level of effort involved two 2½-day sessions with the expert. Additional time, equal to approximately half the time allocated for face-to-face work with the expert, was allocated for one person from IHMC to prepare trip reports pertaining to the current trip, to improve the elicited Concept Maps, and to prepare for the next trip. This amount of time was also dictated by the limited budget, and reflected a significant underestimate of the actual amount of time that was required. Plant personnel participating in the study were tasked with creating accompanying resources such as pictures, digital videos, etc., that would go into the knowledge model. Results of this part of the initiative have so far been limited. An additional goal of the effort was for personnel at the plant to acquire capability to do knowledge elicitation by sitting in on the sessions to observe the techniques of the IHMC personnel.

The approach to knowledge elicitation utilized in this study was the one that has become standard at IHMC over the last several years. Two elicitors were employed: one called a moderator, who interacts with the expert, and a second called a recorder who builds Concept Maps pertaining to the proceedings as they unfold (Coffey *et al*., 2003). *CmapTools* (Cañas *et al,*. 2004), a knowledge modeling toolkit, were used to make electronic versions of Concept Maps as knowledge was elicited. Frequently, "placeholder" maps, small map segments that pertained to promising topics, were created to be revisited later. These and the other maps were consolidated into a knowledge model as part of the work. Details of this work, including attributes of the expert, a description of the sessions, and some preliminary results of the effort follow.

3.1 Attributes of the expert

The expert was highly verbal and knowledgeable in his area. He had experience at another plant before coming to the current facility; he had worked as a consultant, as a college professor, on the ODCM Environmental group, etc. He embodied an interesting combination of knowledge of nuclear physics and acumen pertaining to software for gamma spectroscopy. He had played a major role in the in-house development of mission-critical gamma spectroscopy software for which he could have related many valuable shortcuts and special uses. However, the team did not succeed in eliciting knowledge from him in this area. He was also quite predisposed to digress, and presented an ongoing challenge to keep on-track. Since the expert was computer-savvy, at the end of the first round, he was given the *CmapTools* software and the Concept Maps that had been elicited during the first round of mapping sessions. However, he never produced any additional maps under his own initiative.

3.2 Subdomains of Expertise.

As would be expected of such a long-term professional, the air effluent specialist had significant expertise in several areas. He had deep theoretical and practical groundings in detecting various types of radiation, and in the different types and applications of monitors. He was extremely well versed in regulations relevant to air emissions, and use of the ODCM, the governing document for air effluent detection, analysis and compliance. It was his responsibility to maintain the ODCM; accordingly, he had a significant responsibility to stay current with NRC regulations. He was also expert at source interpretation (determining where radiation came from) – from some part of the plant, as a natural occurrence in the environment, or even brought in by a worker who had undergone radionuclide imaging and had trace amounts of radioactivity is his/her system. He was expert at analyzing the impacts of releases on compliance and many other issues.

3.3 The Sessions

Trip 1. The goal of the first trip was to develop a series of maps that captured the scope of the expert's knowledge. The first Concept Map that was elicited was titled "Cornerstones" (the cornerstones of his job), which were nuclear physics, radiation detection, programming, and people skills. Concept Maps on Regulatory Agencies, Releases – volume and concentration, onsite and offsite, the Software the expert uses including elements that were developed in-house and those that were outsourced, were also elicited. Two somewhat informal maps were created, entitled "Getting things done" which pertained to running analyses, getting equipment fixed, influencing management, etc., and "Learning as you go," which addressed the need for life-long learning and set-aside time on the job to remain current with changes in the field. Other maps pertained to the need to keep up with INPO initiatives, NRC regulations, industry practices, policies dictating requirements, the state of the practice in sensing technology and software, etc.

An important part of the expert's work pertained to monitoring equipment and effluent paths. Maps were created on the various monitor types - liquid and gas, process and effluent. One map pertained to gas monitors - CAMs and area monitors, and problems with unmonitored release paths. The topic of radiation detection, including the types of radiation of concern and the means to detect it, were mapped. Several maps were elicited on reporting doses, source interpretation, and compliance. Data reduction was another concern, and maps were created on counting, summing, and correction factors. Information was elicited from the ODCM such as release points, release information, environmental monitoring controls, etc. The expert was interested in the evolving policy distinctions between verbatim compliance and risk-based assessment of impacts, and the differences between an approach based upon quantity released and one that considered dose to the public. As this listing indicates, the expert had a substantial depth of knowledge in a wide range of areas.

Trip 2. The goal of the second trip was to delve more deeply into issues identified during the first trip. On day 1 of the second trip, Concept Maps pertaining to Algorithms, Germanium Detectors, Managing Procedures, and Review of Surveillance Instructions were created. A review of changes to maps that had been identified on the last afternoon of the first trip was undertaken. During this trip, two maps of particular interest were created. They are interesting because they demonstrate the range of capabilities that Concept Map-based knowledge elicitation provides. The first are called "Activity maps," maps for which the concepts are things that a person *does*. These are quite different than ordinary maps in which the concepts are typically nouns. Activity maps pertaining to Entry-level and Journeyman level activities associated with the expert's job were created.

A demonstration Process map pertaining to the process to establish free release count time was also created. It is presented in the model in the context of the basic organizing Concept Maps and the Journeyman Activity Map, demonstrating the integration of conceptual knowledge and skills (background needed to do the job) through the activity itself (indicated in the Activity map) to the process of carrying out the activity, with links to supporting documentation that the expert uses. Due to the limited time available, only one demonstration of this capability was created. It would have been possible to elicit many more of these linkages from background knowledge through activity to documentation that supports the process, given sufficient time with the expert. At the end of the second trip a preliminary knowledge model was created and presented it to the expert.

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A CASE STUDY IN KNOWLEDGE ELICITATION FOR INSTITUTIONAL MEMORY PRESERVATION USING CONCEPT MAPS

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Abstract. This article contains a description of knowledge elicitation for institutional memory preservation in the nuclear power industry. Because of the large number of pending retirements in the industry, the preservation of expertise is deemed a critical concern, and efforts to do so are extensive. The work described in this article pertains to knowledge elicitation (KE) based on the creation of Concept Maps in the domain of air effluent sensing, analysis and compliance. This paper starts with a brief description of literature pertaining to knowledge elicitation using Concept Maps. This review is followed by a discussion of preparations for this effort made by the elicitors, attributes of the expert, the schedule of events pertaining to the effort, the conduct and results of the sessions, challenges faced along the way, and preliminary results of the endeavor.

1 Introduction

The Nuclear Power industry produces approximately 20% of the energy consumed in the United States, an important contribution to our aggregate energy supply. However, fearsome events that occurred at Three Mile Island more than 20 years ago have had a lingering negative impact on the industry's ability to attract new talent, particularly in more esoteric fields such as nuclear physics. For this reason, this industry faces even greater challenges than most regarding the loss of expertise due to the pending retirement of baby boomers.

The industry has gone to extraordinary lengths for decades to ensure safety and reliability at generation plants, and the industry is aggressively instituting programs to deal with this anticipated loss of expertise. A pro-active approach is necessary since it is estimated that 40% of current workers will be eligible for retirement over the next 5 years. Knowledge retention programs have been initiated in order to capture and understand the skills and training necessary to replace retiring senior engineers, scientists, and crafts persons, and to capture best practices and other undocumented knowledge before it is permanently lost.

This article contains a description of a knowledge retention pilot study, based upon the elicitation of Concept Maps (Novak & Gowin, 1984; Novak, 1998), which took place on-site at a nuclear power plant. The knowledge retention work involved extensive interviews with a nuclear physicist who is an air effluent specialist, using a "tag team" knowledge elicitation (KE) technique, with Concept Mapping as a guiding factor in the sessions. The work with the physicist involved two 2 ½ day site visits, and will include a final wrap-up trip to incorporate the tangibles from the work into training materials, policies and procedures, the records of human resources, etc. The remainder of this article contains a brief description of relevant literature pertaining to knowledge elicitation using Concept Maps, and a description of the case study addressing preparations, characteristics of the expert, the conduct of the sessions, and preliminary results.

2 Knowledge Elicitation using Concept Maps

The following brief literature summary points to some of the prior work that has had an influence on how the current study was conducted. Since Novak and Gowin (1984) originally defined Concept Maps as a means of externalizing what science students knew, several groups have embraced Concept Mapping for KE. Over time, the elicitation of Concept Maps has proven to be an effective means of externalizing an expert's key concepts of a knowledge domain. The elicited Concept Maps have been used to structure what have been termed knowledge models (Ford *et al*., 1991, Ford & Bradshaw, 1995). McNeese *et al*. (1993, 1995) were early adopters of concept mapping techniques to create an external representation of knowledge that is being communicated, and as an organizing factor in KE efforts. One of several studies they cited involved the elicitation of maps from engineers by a team composed of a primary map creator and one or two additional facilitators. Hoffman, Shadbolt, Burton, and Klein (1995) described various types of KE methods including what they termed contrived techniques that bring to bear some sort of experimental or semi-experimental manipulation of the expert's familiar tasks. One type of contrived task involves creation of diagrammatic representations of knowledge in the form of linked

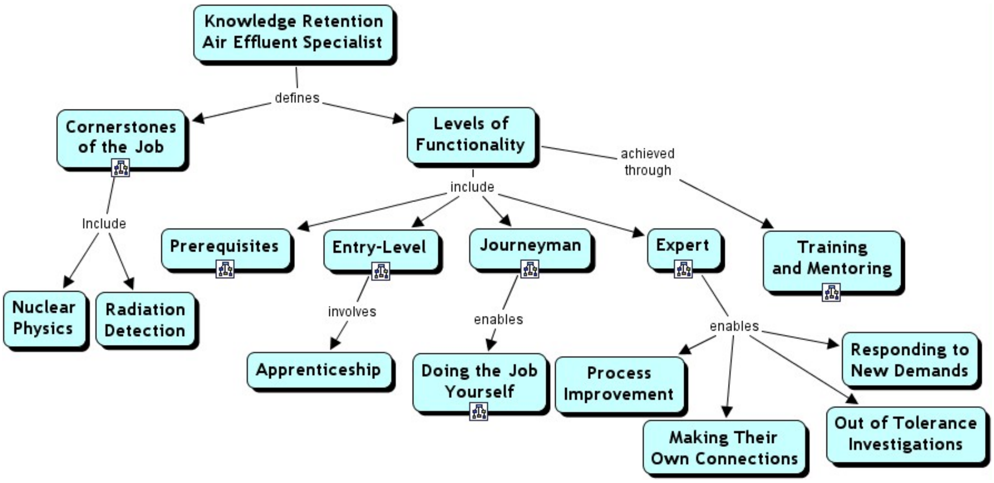

Figure 1. The top-level Concept Map for the Air Effluent Specialist.

4 Organization of the Knowledge Model.

The goal of this work was to create a knowledge model of critical knowledge the expert has. Creating a knowledge model requires organizing the various Concept Maps that have been elicited into a coherent, navigable system that makes explicit the relationships among the various aspects of the expert's knowledge. The Top-Level Map of the knowledge model provides the framework for this organization and provides access to details within the model. Figure 1 contains the top-level map for the work with this expert. It is a simple piece that reflects the fundamental capabilities that a replacement must bring to the job, and the career progression a new entrant in the job might follow. The "Cornerstones" map, which is accessed in the model from the node just below and to the left of the root node in the Top-Level Map, contains the expert's assessment of the requisite capabilities needed to perform the job, and is presented in Figure 2. This map is typical of the level of detail in the Concept Maps that were elicited, and it contains links to other more detailed maps on radiation detection, source interpretation, software, statistics, etc.

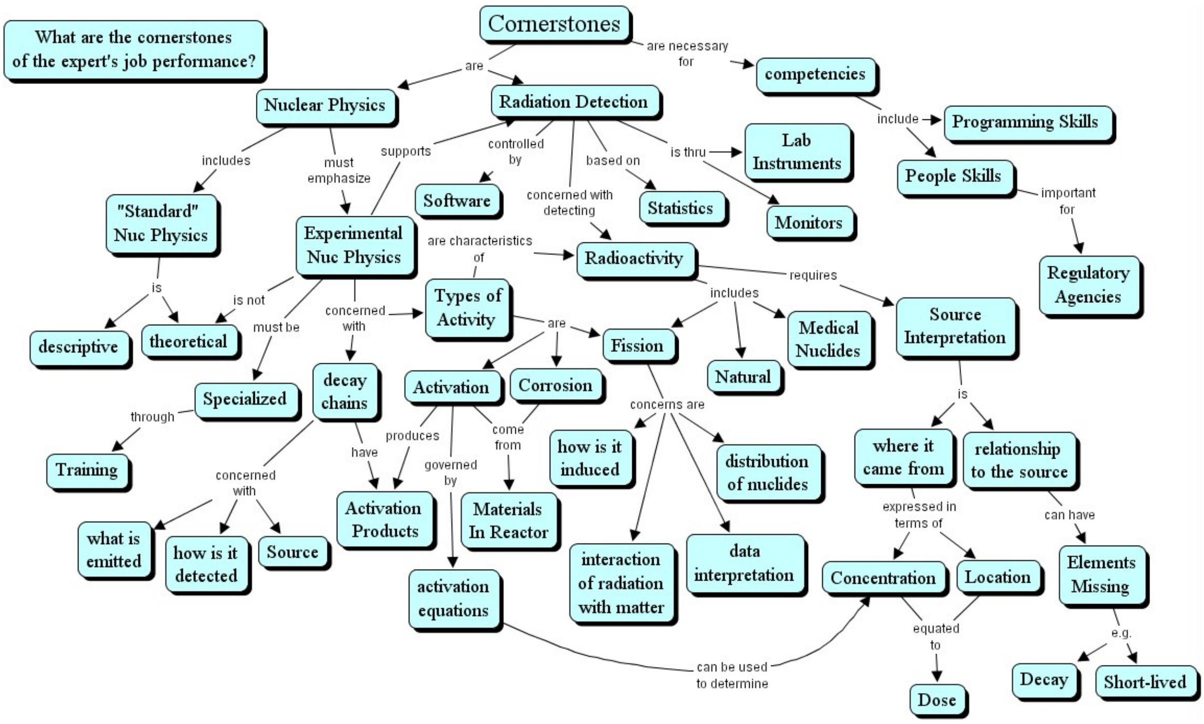

Figure 2. The Cornerstones Map.

The account of a possible career progression that is organized in the top-level map is expressed in terms of prerequisites for the job, entry-level, journeyman and expert-level job performance. The entry-level, journeyman and expert-level nodes contain links to Concept Maps that describe:

- Knowledge and skills necessary for the job
- Activities associated with the knowledge and skills – the Activity Maps.

The "Training and Mentoring" item links to information relating to less formal sources of job improvement that the expert deemed important for a new-hire to know. A total of 34 more detailed Concept Maps were elicited and are linked into the Top-level map. A fully realized knowledge model for Institutional Memory Preservation could be expected to have a balance of traditional Concept Maps, Activity Maps, and Process Maps. The remainder of this section contains additional descriptions of two elements of the model that would bear further development in additional sessions with the expert: the Activity Maps and Process Maps.

4.1 Activity Maps

The technical lead of the pilot asked the elicitors to capture the knowledge and skills necessary to perform the expert's job. After doing so, it became evident that a gap existed in the sense that the knowledge and skills the expert relied on were enumerated, but the actual tasks the expert performed, based upon the knowledge and skills, were not. This gap provided the impetus for the creation of Activity Maps. In an Activity Map, the concepts are the basic activities associated with a job and the relationships among the concepts in the map elaborate the relationships among the activities. In the case of an entry-level worker in the current job, the various activities included managing procedures, doing data analysis from detectors, performing radiation monitor operations such as assessing availability and assisting with troubleshooting, generating reports, and using the computer system.

It was possible to enumerate numerous details under this general grouping of activities, and to create links to other parts of the knowledge model that dealt with various aspects of the activities. The Activity Maps were elicited by starting with the "knowledge and skills" maps and prompting the expert for activities associated with them. Figure 3 contains an Activity Map for the entry-level position. The Journeyman level Activity Map contained many more activities, more than 50 nodes, reflecting the increase in responsibility that comes with progression along this career path.

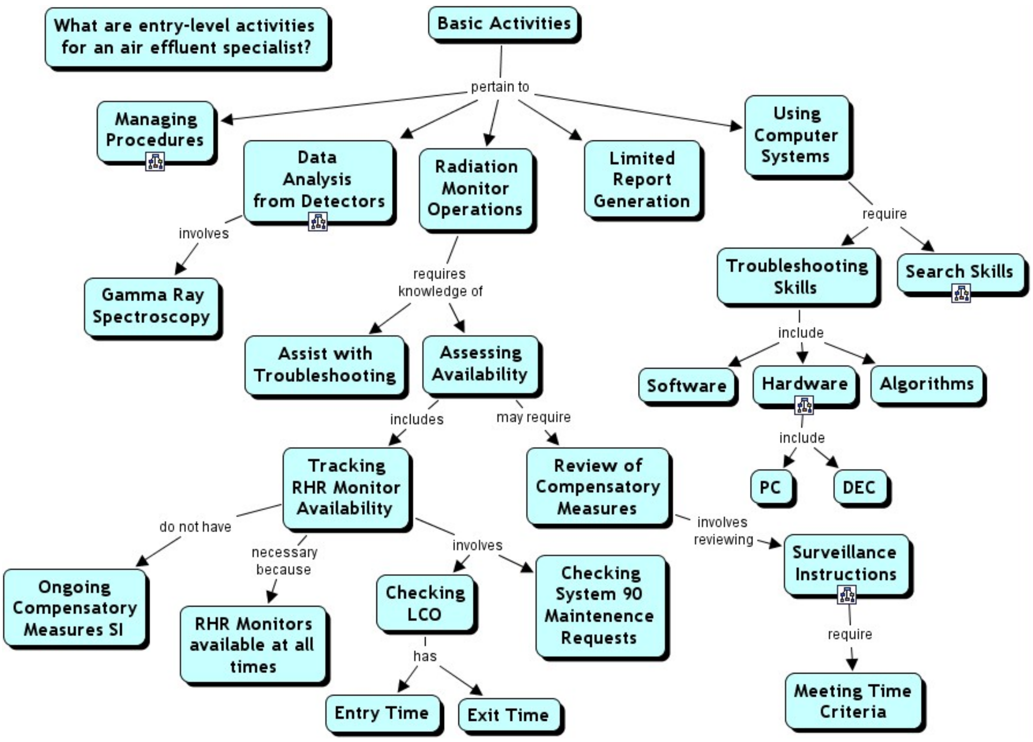

Figure 3. The Activity Map for an Entry-level Employee.

4.2 *The ODCM and process maps*

The nuclear industry seeks reliability and safety by enumerating step-by-step processes for any activity that is amenable to proceduralization. Much of the expert's work was proceduralized. The current work demonstrated a means of creating Process Maps and tying parts of the process directly to pages from the ODCM using *CmapTools*. The demonstration involved the procedure for determining the counting time necessary to analyze a substance for free release from the plant. The Process Map contained a substantial amount of conceptual knowledge such as the categories of things that can be freely released, the ideas of normal and abnormal geometries, the separate steps of determining background radiation count and a Lower Limit of Detection (LLD) for background rate counting time before counting the actual sample itself. The Process Map contained links to tables and other relevant information in the ODCM that were pertinent to the process. Only parts of several tables needed to be used, and the three links in the Process Map were to items that several pages apart in the ODCM, thereby tying together disparate information. The final Process Map presented a succinct representation of the process.

5 Preliminary Results of the Study

Although this is still a work-in-progress, several interesting results have already been obtained. This effort affords a preliminary calibration of the amount of work that can be performed during intensive, on-site, multi-day sessions using Concept Maps. It illustrates a range of uses of Concept Maps for knowledge retention in a highly technical, but simultaneously practical, applied job setting. The work points to an aspect of knowledge retention for which Concept Map-based knowledge elicitation appears highly facilitative – assessment of knowledge and skills required to perform the job, and then assessment of the activities that are based upon the knowledge and skills. Finally, this work, while productive, was not perfectly executed. The work has yielded some lessons learned regarding improvements that could be made to the approach. These topics are discussed in the following sections.

5.1 *Calibration of intensive, on-site knowledge elicitation*

Over the course of two 2½-day trips, a total of 48 Concept Maps were elicited. They were consolidated into 35 maps. A half-day was lost in order to take a visit into the plant to the expert's lab and the counting room. An additional ½ day on-site was used to improve the Concept Maps and to build the knowledge model for presentation at the end of the second trip. Several hours were lost to interruptions that the expert had to deal with, and 2 hours were lost on a day when the expert arrived late. This sort of work is very cognitively intensive, and it is difficult to maintain focus for many hours per day, several days in a row. The half-day of each trip was relatively unproductive. However, through all the interruptions and lost time, this work demonstrates that 10 maps can be produced with a single expert per day over multi-day periods of time.

5.2 *The range of elicited maps*

A wide range of Concept Map types were elicited. While many of them had the expected, traditional, conceptual qualities, many did not. Process Maps have utility in a highly proceduralized knowledge domain, particularly to the degree that it is possible to identify and map difficult or poorly documented procedures. The Activity Maps were deemed to be useful, and could have been carried out into significantly more detail. Furthermore, it was interesting to note that a highly technical person such as this expert, would delve into less concrete areas such as the need to influence management, and the sources of information he utilized to keep current in his job.

The range of maps raises the issue of depth versus breadth in expert knowledge preservation. The current work confirms the generally held wisdom that the more profound an expert's knowledge, the more difficult it is for the expert to explicate. It also became clear that the expert experienced some difficulty assessing what knowledge might be more widely held and what he held individually. If one is trying to preserve what an expert knows, eliciting a somewhat wider and less deep knowledge model might be the best outcome that can be expected. It certainly provides a starting place for more in-depth explorations.

5.3 *What might have been improved?*

Several improvements could be made to the approach that was employed. When all the Concept Maps were organized into a rough model at the end of the second trip and presented to the expert, he had a surprisingly favorable response. It is clear that better buy-in to the process could have been obtained if the expert had a clearer idea, earlier in the process, of where the work was going. Attempts were made to make the anticipated results of the work clear to the expert at the outset, but presenting prior work did not have as much impact as the expert actually seeing the emerging model of his own knowledge. Experts should be made privy to the way the knowledge will be organized as soon as it is feasible to make a meaningful presentation. A second element that could have been improved would have been to have shorter trips, and shorter duration sessions with the expert. Due to time and travel constraints, this was not, and may not typically, be possible.

6 Summary

This paper contains a case study in the use of concept mapping for institutional memory preservation. It describes work in the nuclear power industry with an air effluent specialist, a highly applied knowledge domain. This work led to a variety of representations in Concept Maps – traditional Concept Maps of the sort described by Novak (1984), Process Maps with links to documents that support performance of the process, and Activity Maps that capture and elucidate the activities in which an expert engages. The work described here is preliminary. The intention is that knowledge elicited in this study will be rolled into training programs for workers who will replace retiring personnel who have performed these activities. The ultimate impacts of the elicited knowledge are still to be determined.

7 Acknowledgements

We wish to thank Professor Joseph Novak for many years of guidance and collaboration in helping us learn the craft of Concept Mapping. We also wish to thank Professor Robert Hoffman for his contributions to the field of Knowledge Elicitation. Both have had significant impact on this work.

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'BUT IS OUR CONCEPT MAP ANY GOOD?': CLASSROOM EXPERIENCES WITH THE REASONABLE FALLIBLE ANALYSER

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Abstract: Classroom concept mapping presents teachers with the problem of how to arrange that learners get feedback on the quality of their concept maps. To address this problem, a software analyser (named the RFA) has been developed that generates scores and hints for student maps by comparing them to an expert map. The analyser is fallible: many of its assessments will be initially incorrect. But it is also reasonable: the student is able to argue for a more favourable assessment. This paper reports classroom trials which indicate that high school students' experience of concept mapping is enhanced by the RFA. Students enjoy arguing with the system, accept its scoring as fair, welcome its hints, and are frequently stimulated to revise their maps to accommodate the feedback obtained.

1 Introduction

Envisage a high school classroom in which students are nearing the end of their work on some topic. In pairs, they have been busily making concept maps to summarise their understanding of the material. One pair has nearly finished as the teacher approaches. She says something encouraging but the students are not quite satisfied with this level of reaction. They want to know: 'But is our concept map any good?'.

The students' question is a reasonable one but it presents the teacher with a problem. Her response could be any one of at least three kinds:

- She could sit down with the students and study and discuss their map. Potentially she can provide rich feedback based on its contents, bringing to bear an own expert understanding of the topic as well as detailed knowledge of her students' learning.
- She could suggest that students self-assess their own map, perhaps by discussion with classmates in which maps are compared with a view to agreeing on improvements.
- She could say 'Your concept map doesn't matter, it's what you learned in making it that counts. Besides, everybody's understanding is unique. So how can a concept map be objectively assessed?'.

The first response is ideal but also perhaps, idealistic. With this approach the teacher gains knowledge of her students' progress and the students benefit from high quality feedback. Unfortunately, since classes normally contain many pupils it is feasible only seldom. The second response might be productive in some contexts but it is tricky since it implies a possibly lengthy process of interaction between peers whose ability to provide useful assessment is uncertain. As for the third response, it seems unhelpful and misguided. Of course the process of concept mapping is more important than the product and it is true that a map provides a personal view of a domain. But surely, a summary of routine curriculum material ought to capture key features in more or less recognisable ways. Feedback plays a vital role in learning generally and to disregard the possibilities that concept maps afford for feedback is to miss an opportunity and also, possibly, to undermine students' confidence in concept mapping.

The development of the Reasonable Fallible Analyser (RFA) was motivated by a concern that in practice, many students are making concept maps for which they get little or no feedback. The RFA is a computer program that compares a student's concept map to one produced by an expert or able peer and produces a score along with hints for improvement. Because it imposes no restrictions on students' language, the analyser is fallible: many of its assessments will be initially incorrect. But it is also reasonable: the student is able to argue for a more favourable assessment.

The remainder of the paper is in three main parts. First, a brief system description of the RFA is offered. Second, some classroom experiences are reported that are based on trials with the RFA in an Edinburgh high school. The trials indicate that high school students' experience of concept mapping is enhanced by the RFA. Students enjoy arguing with the system, accept its scoring as fair, welcome its hints, and are frequently stimulated to revise their maps to accommodate the feedback obtained. Third, some discussion is offered around the content of this work, including its relationship to the wider context of assessment.

2 The Reasonable Fallible Analyser

The user interface to the RFA is shown in Figure 1 below. The design of the system has been reported elsewhere (Conlon 2004) and only a brief summary is given here. In contrast to other concept map analysers (Biswas et al 2001, Chang et al 2001), the RFA aims to be extremely flexible and unobtrusive upon the normal concept map building process. Thus a first design goal was for avoidance of restriction to particular subject domains, vocabularies, or even map building environments — the RFA (when armed with a suitable comparison map) should be able to analyse any map on any topic, implemented in any software environment, using language freely chosen by the student. This implies fallibility on the system's part, because unrestricted concept maps will sometimes contain text that the analyser cannot reliably interpret. So a second design goal was for openness: the system should be able to negotiate its assessment with the student. Openness is not simply a tactic to compensate for the system's lack of ability, however. It also reflects a promotion of the learner to a status of sharing responsibility for the learning (and assessment) process. This is consistent with recent thinking (discussed later) about formative assessment in education and also with trends in the design of computer-based learning environments (Morales et al 1999). It seems particularly appropriate for concept mapping which from the start has been motivated by the principle of 'learning how to learn' (Novak and Gowin, 1984).

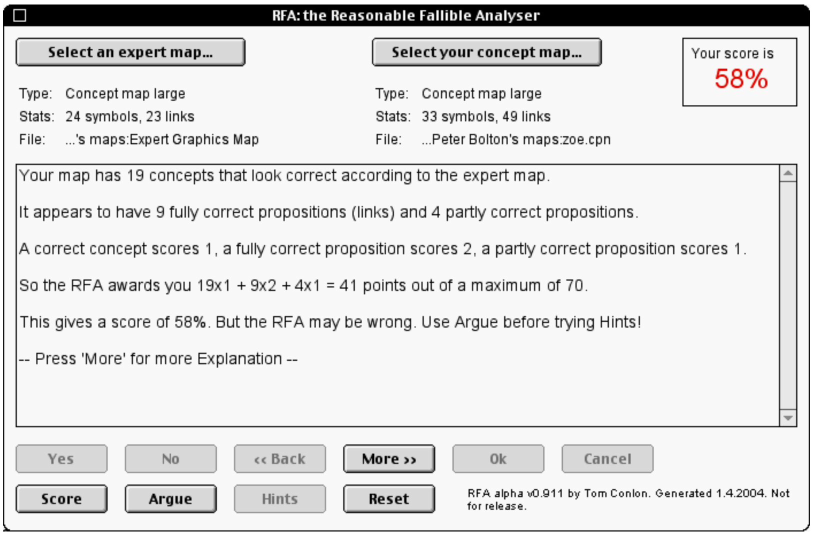

Figure 1 User interface to the RFA

In a little more detail, the analyser was designed to satisfy the following criteria:

- The system should be interoperable with a variety of concept map building tools. At present however it accepts only maps in the format of Conception (www.parlog.com).
- No special pre-processing ought to be necessary to enable any concept map to serve as an expert map.
- The system ought not to depend upon assumptions about the content of student maps. In particular, maps are not expected to be constrained to a pre-specified lexicon.
- Scoring of student maps should use a formula that credits both correct concepts and correct propositions, as specified by the comparison map. Figure 1 indicates the formula that is currently implemented; of course, other formulae are possible. A transparent explanation for scores should be provided.
- When the system detects that a concept or proposition mismatches anything in the comparison map, the student ought to have the opportunity (via an 'Argue' function) to claim that an equivalence was intended. Thus, the initially computed score should be regarded as provisional and capable of being upgraded by negotiation.
- The system should be able to offer hints relating to missing concepts, missing links, and dubious relationships. Recommendations to add new concepts should be limited to those that can be attached to concepts that are actually present in the student's map.

The RFA is implemented in LPA Prolog++ (www.lpa.co.uk) and runs under both Windows and Macintosh operating systems. To boost its general language capabilities the system incorporates WordNet, a lexical database accessible from Prolog that incorporates a dictionary of 200,000 words (Witzig 2003). In addition, a separate User Dictionary is incorporated which can be edited to define specialist synonyms that would not be expected to occur in WordNet.

As Figure 1 indicates, when a map score has been initially computed the student is invited to negotiate an improved score by means of an 'Argue' button. Three types of argument are then possible. One is a protracted system-led interaction in which the student is asked to confirm or deny the presence of possible defects that have been detected in the map. This option is useful for novices but perhaps frustrating for experienced users who should be able to infer (from the score explanation, which can be viewed in far more detail than the screen shot shows) in what way the RFA's analysis is erroneous. Therefore two other types of argument are available which enable the student to take more initiative in the dialogue, by identifying respectively specific concepts or propositions that have been misconstrued by the system.

3 Classroom Trials

When a limited prototype version of the RFA was tested under laboratory conditions with a sample of student concept maps, performance seemed promising. The RFA's scores correlated quite closely with scores calculated manually by an expert human assessor. The system's pre-argument scores under-rated student maps by an average of 25% but the argument process reduced the difference to an average of 16%. Thus the RFA demonstrated its fallibility, but also its reasonableness in adjusting its assessments in the direction of greater accuracy in response to argument.

Classroom trials with the RFA were undertaken in an Edinburgh high school in March 2004. The trials were intended to answer some basic questions. Did students find the analyser usable? Was it easy to learn, effective in providing fair and helpful feedback, and enjoyable to use? Of particular concern was students' perceptions of the analyser's fallibility and its provision of an argument function. Would they take this function seriously or perhaps, try to 'cheat' by claiming as synonyms terms that were not genuinely synonymous? In addition, although it was not attempted at this stage to quantify the effect on learning, the effect of the RFA on the overall concept mapping process was of interest. Would students be stimulated by interaction with the RFA to revise their concept maps?

During the trials, the RFA was made available to 40 students aged 14-16 over a period of two weeks. The students were following courses in computer technology at a variety of academic levels. The class teacher, who regularly incorporated concept mapping activities within his teaching, had students engaged in the preparation of concept map summaries of course material using Conception (www.parlog.com) software. This much was more or less conventional practice. The novel feature was that students were told that on these occasions, it would be possible to use the RFA to get feedback on their maps. Instruction on the RFA was minimal: students were issued with a one-page handout that summarised the operation of the user interface. Expert maps had been prepared in advance by the class teacher and their file names were displayed on the class whiteboard. No use was made of the RFA's capability to accommodate specialist vocabulary within the User Dictionary.

The classroom trials produced data from three main sources: direct observation by the class teacher and the researcher; log files generated automatically by the RFA that (unbeknown to students) recorded details of user interaction; and a questionnaire that was completed by students immediately after the lessons. The questionnaire elicited responses to a set of provided statements using a four-point Likert scale: 1 = Disagree strongly, 2 = Disagree, 3 = Agree, 4 = Agree strongly. For summary purposes, it will be convenient below to structure the results around categories of questions from the questionnaire, supplementing these with evidence from direct observation and log files where appropriate.

3.1 Attitudes to Concept Mapping

Clearly, students' attitudes to the RFA need to be interpreted in the context of their attitudes to concept mapping generally. These attitudes are summarised by the questionnaire responses shown in Table 1 where the percentages represent the total of students who answered either 'Agree' or 'Agree strongly' with the statement. As can be seen, students are largely positive towards concept mapping and they favour computer tools for map construction. An analysis by gender revealed that boys more frequently than girls identified concept mapping as hard work — 37% of boys compared to 17% of girls agreed with this statement. However, girls were heavily outnumbered in our sample (only 12 females out of 40 students) and neither this nor any other gender difference reported here is statistically significant.

Statement	Agreement
Concept mapping helps me to learn.	95%
Concept mapping is hard work.	31%
If I had the choice, I wouldn't make concept maps again in future.	23%
I prefer paper-and-pencil to a computer for concept mapping.	15%

Table 1. Students' attitudes to concept mapping

3.2 Attitudes to Feedback

As mentioned previously, a hypothesis that motivated the development of the RFA was that students generally are making concept maps for which they get little or no feedback. This hypothesis was tested by the two questionnaire statements shown in Table 2. The lack of feedback is confirmed. Furthermore, it matters: a very large majority of students does care about knowing whether their maps are good or bad.

Statement	Agreement
Until now, when I have constructed a concept map I haven't known whether it's good or bad.	69%
It's important to me to know whether my concept map is good or bad.	92%

Table 2. Students' attitudes to feedback

3.3 RFA as a Stimulus to Map Revision

The class teacher encouraged students to use the results of each interaction with the RFA as a stimulus to revise their maps. In practice, students were observed to do this often and it was clear that they were motivated in their map-making by the prospect of submitting their maps to the RFA for analysis. As Table 3 shows, students agreed that the RFA was effective in this role.

Statement	Agreement
Using the Analyser made me want to redo parts on my concept map.	87%
I would put more effort into my concept maps in future if I knew they were going to be scored by the Analyser.	90%
Using the Analyser made me realise that I need to learn more about the subject matter of my map.	79%

Table 3. The RFA as stimulus to map revision

3.4 Attitudes to the Argument Function

Observation revealed that students found the RFA easy to use. The '10-minute rule' proposed by Nelson (1980), whereby the ability of a novice to be able to learn to use a new computer system within 10 minutes is taken as the criterion of whether the system is easy to learn, seems to be broadly met by the RFA. However, it was evident that students sometimes skipped over the text that provided detailed explanation of how their maps had been scored and they often showed hesitancy when selecting between different options of the Argument function. Nevertheless, students were quite tenacious in argument and they commonly achieved gains of around 20% over the system's pre-argument scores. Most of these gains were due to the student's identification of mismatches between the textual rendering of concepts in the two maps: in every case the mismatch was plausible, that is, no cheating was encountered.

Students' questionnaire responses (Table 4) confirm the evidence of classroom observation that they generally enjoyed arguing with the system, accepted its scoring as fair, and were basically honest in their approach. In fact, students were surprisingly satisfied even by the RFA's pre-argument scores even although these typically undervalued their maps considerably. The belief on the part of 44% of students that cheating would necessarily be detected by the system is misguided, of course. In fact, the RFA is very gullible. This is not a point that was stressed in class and it remains to be seen how students' attitudes to the system may change as increased exposure (presumably) reveals its gullibility.

A couple of gender differences in this area are suggestive. First, girls were more satisfied with the scores their maps were awarded than boys: 92% of girls regarded the pre-argument scores as fair and for post-argument scores this rose to 100%. The corresponding figures for boys were 63% and 96%. Second, girls were more likely to believe that cheating would be detected: 58% of girls expressed this view as compared to 37% of boys.

Statement	Agreement
It was fun to use the 'Argue' button of the Analyser.	85%
The score that was given to my map(s) by the Analyser even before I used the 'Argue' button was fair.	72%
The score that was given to my map(s) after I used the 'Argue' button was fair.	97%
It was frustrating to argue with the Analyser.	23%
I was keen to try to raise my map's score by arguing with the Analyser.	92%
When arguing with the Analyser, I was tempted to cheat by claiming that different words meant the same thing.	28%
If I tried to cheat when arguing with the Analyser, it would be certain to find me out.	44%
When arguing with the Analyser, I always did my best to answer its questions as honestly as possible.	90%

Table 4. Attitudes to the Argument function

3.5 *Perceptions of Scores and Hints*

As Table 5 shows, students generally expressed approval of the RFA's score explanations and hints. For the former, a higher proportion of girls (92%) was satisfied than boys (63%). More than three-quarters of students claimed that they would like to use the RFA with all their future map-making activities. The class teacher agreed that the RFA's hints were well-founded and likely to be helpful to his students' learning. The system's ability to generate a Certificate summarising these hints, which students could print and take away, was especially welcomed (for an example see Figure 2).

Statement	Agreement
The Analyser is good at explaining how it calculates its map scores.	72%
The hints provided by the Analyser were helpful.	85%
If I had the choice, I would use the Analyser every time I made a map.	77%

Table 5. The RFA as stimulus to map revision

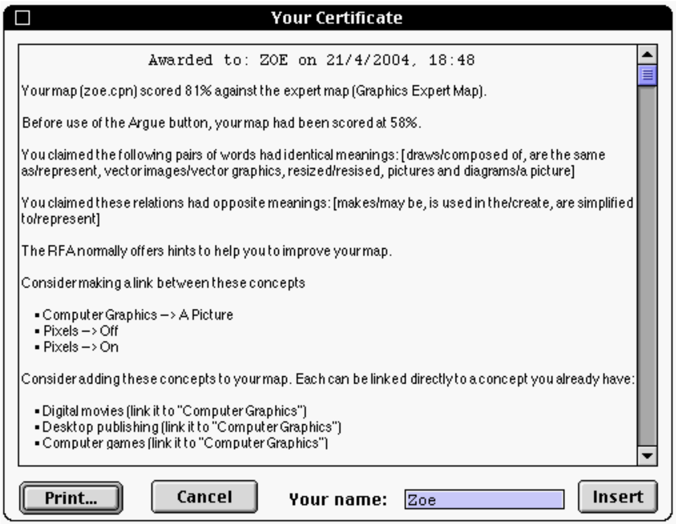

Figure 2 A post-argument certificate generated by the RFA

4 Discussion

In this section two central issues are discussed. First, the RFA is related to the wider context of assessment in education. Second, the scope of use of the RFA and its appropriate associated pedagogy are considered.

4.1 Formative Assessment

A conventional distinction made in the literature is between formative and summative assessment. Briefly, formative assessment aims to produce information which helps students to improve their learning. The information may be directed at the learner (formative self-assessment) or at the teacher (diagnostic assessment) or possibly, at both. Summative assessment aims to produce information which summarises what the student has learned, for example for the purpose of reporting to parents or awarding academic credits. Primarily, the RFA is intended to contribute *formative self-assessment*. It has potential in diagnostic assessment, even in its present form, and it should be straightforward to develop (for instance) a variant of the system that can batch-process a class set of concept maps and generate a profile of represented concepts and relationships which can guide future teaching action.

The development of a new technology for formative assessment of concept maps is timely. In Scotland and perhaps in other countries too, education policy makers now urge schools to make more use of formative assessment (Simpson 2003). The reasons are several and include awareness of the limitations of summative assessment, the need to promote self-monitoring, self-motivation and self-reliance among learners, and a general desire to shift from a teacher-centred, transmissional pedagogy towards a learner-centred, constructivist one. The effectiveness of concept mapping for learning has been demonstrated many times but its potential contribution to formative assessment seems to have been neglected. Summative assessment, on the other hand, has received a lot of attention from concept map researchers (e.g. Rice et al 1998, Ruiz-Primo et al 1998, West et al 2002). This seems odd, not only because concept mapping is most naturally seen as a developmental tool but also because formative assessment generally is much less beset by the reliability and validity issues which have predictably dominated discussion about the role of concept mapping in summative assessment.

4.2 Scope and Pedagogy

The scope of the RFA (by which is meant, the range of contexts in which its use is appropriate) and its associated pedagogy need to be clarified by further research. However, since the system depends upon the availability of a comparison map it seems likely that exploratory forms of concept mapping (for example, mapping out a plan for a piece of creative writing) are outwith the RFA's scope. However, much classroom concept mapping seems to be about *summarising* rather than exploring. Commonly, students' maps are abstractions of routine curriculum subject matter. For such tasks, use of the RFA should be feasible.

A pedagogy that incorporates the RFA, and which generalises the approach used in the classroom trials, is illustrated in Figure 3. Here, labels represent processes to be accomplished by the student. Although more investigation is needed, it seems predictable that the processes 'Review domain' and 'Discuss with teachers/peers' are likely to be crucial to ensuring that the RFA's feedback is productive within a cycle of meaningful learning. Without them, there is a danger that some students will engage in a shallow edit-submit-edit cycle that utilises feedback only at surface level and which limits the scope of learning to the names of concepts and relations. Such students might succeed eventually in bringing their map into alignment with the expert map but without much change in their own personal conceptual frameworks.

The scaffolding (support) which the teacher supplies initially with the task will also be important. A study by (Chang et al.2001) compared experimentally two groups of high school students who were concept mapping in the domain of biology. One group was scaffolded initially by the provision of a partly completed map whilst the other group built maps from scratch. Both groups used the same concept mapping environment that provided feedback based on an expert map and which imposed (even for the 'scratch' students) a prespecified list of concept and relation names. Tests of learning showed significantly better results for the scaffolded group.

Generally in Scotland, skilled classroom teachers acknowledge that the extent and form of scaffolding is a key factor in learning and that it is often necessary to adjust scaffolding so as to differentiate between learners at different stages of development. In classroom trials with the RFA, scaffolding was provided by the class teacher by eliciting a partial list of concept names through whole-class brainstorming prior to the commencement of concept mapping. If Chang's study is a guide, it would be useful to consider the option of making available (to some students) a partially completed map file. On the other hand, the incorporation into pedagogy of the RFA might enable students to succeed with tasks that are more open-ended: their initial maps may be wide of the mark but with feedback they can be improved.

It remains to be seen how attractive will be this pedagogy to teachers. There is some evidence that the uptake of concept mapping by high school teachers is low (Conlon & Bird 2004). No doubt several reasons can be found for this but among them is probably the fact that concept mapping presents teachers with the problem of how to arrange that learners get feedback on the quality of their maps. The RFA addresses this problem and adds to concept mapping some additional benefits that even traditionally minded teachers should appreciate: a clear goal for students who are motivated to submit their maps to the system; an enjoyable and productive use of new technology; and a liberation of the teacher's time that makes room for individualised coaching and other creative teaching activities.

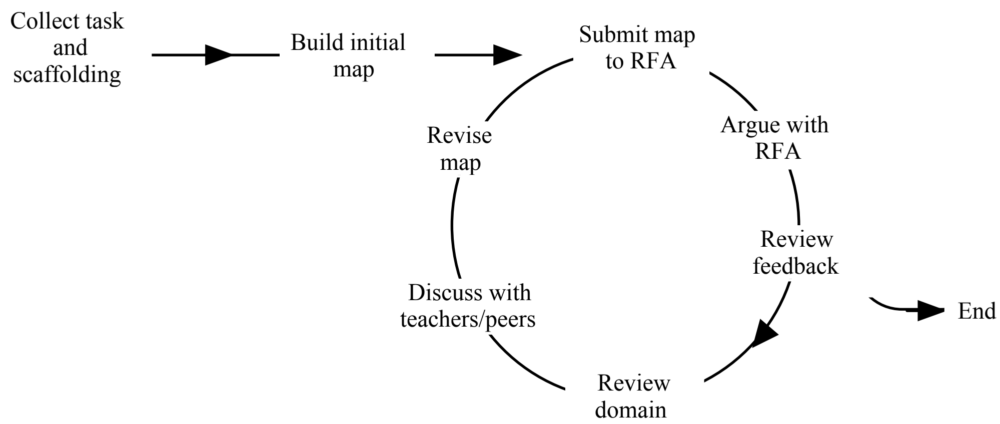

Figure 3 A pedagogy for concept mapping with the RFA

5 Conclusion

There is clear scope for development of the RFA. In particular, provision could be made to enable the system to operate more incrementally, that is, as coach rather than critic; the argument function could be enriched; and the system could be extended to exploit a multiplicity of comparison maps on a given domain, rather than relying on only a single comparison map.

Such developments however will need to be guided carefully by theories and empirical trials. The trials reported in this paper indicate that even in its present form, high school students' experience of concept mapping is enhanced by the RFA. Students enjoy arguing with the system, accept its scoring as fair, welcome its hints, and are stimulated to revise their maps to accommodate the feedback obtained. Because the RFA enables formative assessment of students' concept maps without imposing any restrictions upon their freedom of expression, and because of its flexibility in adapting to each new domain merely by the addition of a comparison map, it is claimed that this technology and its associated pedagogy represent a significant contribution to concept mapping.

6 Acknowledgements

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LINKING PHRASES IN CONCEPT MAPS: A STUDY ON THE NATURE OF INCLUSIVITY

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Abstract. Computerized analysis of a concept map (CM) syntactic and semantic characteristics can become a complex task, whose results can be doubtful if the map contains either graphical or textual ambiguities. In the specific case of using CMs in education, the use of the results of automatic structural analysis of a map in learning assessment implies the existence of entirely computable maps, capable of coping with the inherently ambiguous nature of the language used in their construction, which results in imprecise concepts and linking phrases. This imprecision hinders initiatives toward computer processing of CMs. In this paper, we present a strategy to minimize the imprecision of linking phrases, by analyzing the nature of inclusivity in hierarchies of concepts in CMs. We present a formal extensible notation capable of distinguishing among the subtleties of these hierarchies. Based on this formalization, it is possible not only to determine precisely the dimension of inclusivity specified in a proposition, but also to define methods capable of determining the semantic distance between propositions in CMs.

1 Introduction

During the process of learning, learners construct a reality or interpretation of reality based upon their perceptions. Traditional conceptions of learning emphasize the object of our knowing rather than the process of coming to know what is actually learned. Constructivism, on the other hand, focus 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).

"Concept maps" (Novak & Gowin, 1984) and other knowledge representation tools – of which the most widely known are "Semantic networks" (Fisher et al., 1990) and "Mind maps" (Buzan & Buzan, 1993) – have been used in computer-based applications and paper and pencil applications, in accordance with the learning models proposed by constructivist theorists such as Ausubel, Vygotsky, and von Glasersfeld. They support the activities of learning, teaching, research, intellectual analysis, and organization of knowledge resources, by mimicking the workings of the brain, especially working memory and long-term memory (Fisher et al., 2000).

Concept mapping is a process of meaning construction. The concept maps (CMs) that result from this process are diagrams – usually bi-dimensional – that illustrate relationships between two or more concepts. Concepts can be defined as regularities perceived in objects, events, situations, or properties (Novak & Gowin, 1984). Another common definition states that concepts are objects, facts, situations, or properties that possess common criterial attributes and are represented by the same symbol (Ausubel, 2000). A proposition is a relationship or association between two or more concepts.

CMs are based in three fundamental characteristics: hierarchical structure, progressive differentiation, and integrative reconciliation (Novak & Gowin, 1984). The hierarchical structure of a CM is based on the concept of **inclusivity**: each concept inserted in a map has a level of inclusivity somehow comparable to the levels of the concepts already in the map. This is not necessarily related to the physical containment sense of the word "inclusivity". In the context of CMs, inclusivity is a concept of epistemological nature, fundamental for the construction of meaning. In CMs, the idea of inclusivity alludes to the very nature of hierarchies and their expressiveness. A more inclusive concept is one that, according to the learning task in progress, can be considered a superordinate concept.

Linking phrases used to label propositions can be considered values assigned to binary relations that exist between concepts. These values can be organized in hierarchies of **super-types**, according to the semantic relationship (**dimension**) resulting from their use between two concepts, as in Fisher (1988). This categorization is important for the automatic analysis of maps and for the determination of levels of similarity between propositions. For example, in the propositions <CAR has WHEEL> and <CAR depends on FUEL> the linking phrases <has> and <depends on> are instances of the super-types **Partition** and **Dependency**. They imply partition and dependency dimensions to the relations between the concepts. Figure 1 illustrates a concept map in which <HUMAN LEARNING> is the concept of highest inclusivity degree. It is related to the concepts <COGNITIVE LEARNING>, <AFFECTIVE LEARNING> and <PSYCHOMOTOR LEARNING> according to a **Classification** dimension.

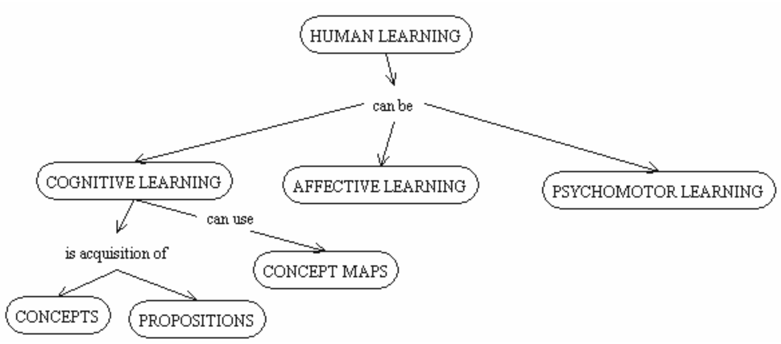

Figure 1. Concept map about human learning

Linking phrases in propositions not only determine the semantic dimension in which two concepts are related from a hierarchical perspective. They are also fundamental in the processes of **progressive differentiation** and **integrative reconciliation**, because they limit the scope of the differentiation or reconciliation in progress.

Progressive differentiation is the process of meaningful learning in which learners increase the degree of elaboration of a concept as they increase their knowledge about it (Ausubel, 2000). In order to detect progressive differentiation in a concept map, it is necessary to observe if more inclusive concepts are related to less inclusive concepts in certain dimensions. In Figure 1, the concept <COGNITIVE LEARNING> is progressively differentiated.

Integrative reconciliation, on the other hand, occurs when the learner identifies dimensions of relationships between components not previously connected. In **superordinate integrative reconciliation**, the learner identifies a more inclusive concept not initially present in the map or not initially connected to the less inclusive concepts. **Combinatorial integrative reconciliation** happens when the learner perceives dimensions of relationships between concepts that, according to the learning task, are not part of an identifiable hierarchy. The learner does not identify a more inclusive concept, but discerns the need of relating concepts present in different branches of the map.

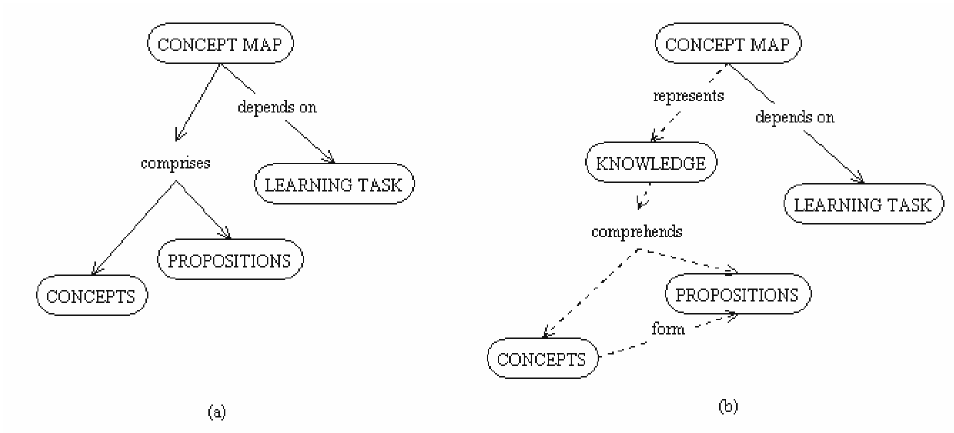

Figure 2. Progressive differentiation and integrative reconciliation in concept maps

Figure 2(a) illustrates the progressive differentiation of the concept <CONCEPT MAP>. Less inclusive concepts are related to <CONCEPT MAP> in a **Partition** dimension and in a **Dependency** dimension. Figure 2(b) illustrates two situations of integrative reconciliation: superordinate reconciliation (among the new concept <KNOWLEDGE> and its subordinates <CONCEPTS> and <PROPOSITIONS>) and combinatorial reconciliation (in the binary relation <CONCEPTS form PROPOSITIONS>.

This analysis provides an insight on the importance of linking phrases in concept maps, as well as their classification in the semantic dimensions they represent. The task of linking concepts into propositions is the most critical step in constructing CMs (Jonassen, 1996; Cañas, 2003), because this is the moment in which meaning is being constructed and refined. The objective of this article is to shed some light on how linking phrases can be automatically computed, not only with respect to the dimensions they represent, but also on how their meanings can be compared. It contains five sections, including this introduction. In section 2, we present some simple cases of ambiguity in CMs. In section 3, we present an excerpt of the computable formalization (grammar) for describing inclusivity in CMs. Section 4 presents a scenario of use: the CMTool learning environment, in which the grammar is used to determine semantic distances between two given propositions. We conclude the article in section 5.

2 Ambiguity in CMs

CMs are simplified representations of a person's cognitive structure (Novak, 1984; Peña et al., 1996; McAleese et al., 1999). As mentioned in McAleese et al. (1999), there is strong evidence that the representations we use in thinking are largely not language based or language dependent. Rather, people think with mental imagery and skeletal representations of ideas. These concepts, maintained abstractly in the cognitive structure, are highly interconnected, forming propositions that express new dimensions of the original concepts. However, ambiguous natural (human) language is the main tool in the process of concept mapping. In CMs, both concepts and propositions are represented in natural language and, as a result, are subject to ambiguity.

The ambiguity resulting from the process of concept mapping makes it more difficult to automatically analyze and assess learning in CMs. Although this ambiguity can occur in concepts or propositions, we focus on the latter, because of the importance of the process of connecting concepts in concept mapping. For more information on disambiguating concepts in CMs, refer to Cañas et al. (2003), in which a **disambiguator algorithm** based on information from WordNet (Fellbaum, 1998) is presented. Other WordNet-based initiatives in determining word sense can be found in Li et al. (1995) and Nastase & Szpakowics (2001).

The process of connecting concepts via linking phrases is critical because of the effort exerted by the learner in trying to determine exactly the nature of the relationship between the concepts (Jonassen, 1996). Figure 3 illustrates an example of propositional ambiguity, considering the concepts are unambiguously determined.

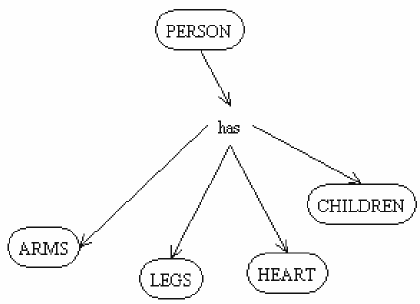

Figure 3. CM with ambiguous use of linking phrase (<has>)

In the proposition <PERSON has ARM> the dimension the learner probably wants to express is a **Partition** dimension connecting and expanding the concepts <PERSON> and <ARM>. On the other hand, in the proposition <PERSON has CHILDREN>, the underlying idea is not of a partition dimension, but rather of an "offspring" or "tutoring" dimension. A computerized analysis of such a CM would have to face this ambiguity and would not be able to assess the students understanding of the learning task straightforwardly. In the example given in Figure 3, the nature (super-type) of the linking phrase can be inferred from the concepts being connected and from the context (learning task) under analysis. This can be done by a disambiguator algorithm capable of informing (e.g. through usage probability) the dimension that best fits the proposition. However, more complex CMs are hard to be analyzed if the analysis is not supported by some kind of systematization of possible dimensions of inclusivity. Another example of ambiguous use of a linking phrase, this time in a more complex domain, is given in Figure 4.

The propositions <ARTIFICIAL NEURAL NETWORK consists of LAYERS OF NEURONS> and <ARTIFICIAL NEURAL NETWORK consists of MATHEMATICALLY MODELED NEURONS> do not express exactly the same idea: the basic foundation element of artificial neural networks are neurons, which are usually organized in layers. Thus, a traditional computerized system designed to assess students understanding of the topic would not be able to discern whether the student understands that the dimension of the relationship between neural networks and neurons is a **Partition.Aggregation** dimension and between neural networks and layers is a **Partition.Organization** dimension. In this case, a disambiguator mechanism could use contextual information (extracted from nearby concepts or from the learning task underway) to derive the correct meaning of the linking phrase. Another possible solution would be to request further explanation from the student drawing such a map. This further explanation could be given by determining explicitly the nature (super-type) of the linking phrase. In both cases, however, an initial step is to create a categorization of the linking phrases, either for use by the disambiguator, or for student explanation.

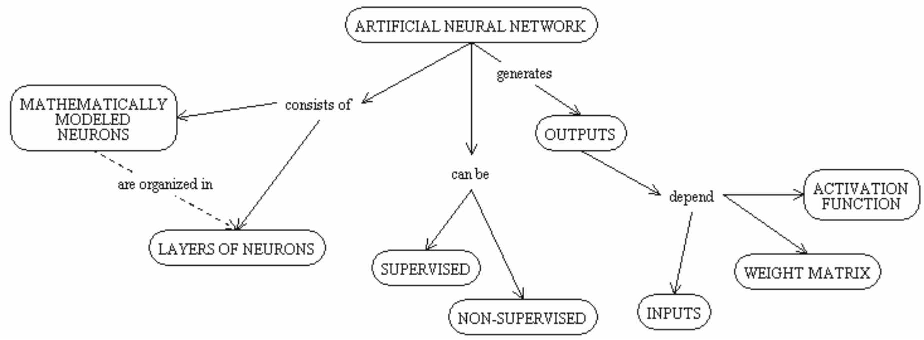

Figure 4. CM with ambiguous use of linking phrase (<consists of>)

3 An EBNF Grammar Definition of Inclusivity in CMs

3.1 The EBNF notation

In order to make it possible to create a categorization of linking phrases capable of being parsed by a computer system, and also capable of being extended as needed, it is necessary to use a notation sufficiently formal to allow for parsing and calculations of distances between two points in the categorization. The EBNF notation defined in the ISO/IEC 14977 standard (ISO/IEC 14977:1996(E), 1996) is a formal mathematical notation used to describe a language. It consists of a collection of rules (**productions)** collectively called a **grammar**. It is widely used in Computer Science to formally define the grammar of a programming language, operating system commands, and other types of computer input.

In EBNF, each production consists of a non-terminal symbol and an EBNF expression separated by an equal sign and terminated with a semicolon. The non-terminal symbol is called **meta-identifier** (a syntactic constant denoted by an English word) and the EBNF expression is its definition. The EBNF expression is composed of zero or more terminal symbols, non-terminal symbols, and other metasymbols. EBNF cannot capture non-context-free grammars, so an EBNF grammar may need to be augmented with notes on semantics, in free-form English (although other more formal approaches may be used). An exemplifying grammar defining the mathematical set of integers is illustrated in Figure 5.

```
integer = unsigned integer | ‘+’,unsigned integer  |  ‘-’ unsigned integer;
unsigned integer = digit | unsigned integer, digit;
digit = ‘0’ | ‘1’ | ‘2’ | ‘3’ | ‘4’ | ‘5’ | ‘6’ | ‘7’ | ‘8’ | ‘9’;
```

Figure 5. Example definition using EBNF

3.2 The Inclusivity Grammar

Some attempts to classify and categorize binary relations connecting two concepts (or ontological nodes) exist in the knowledge representation literature. Yudelson et al. (2003) list two initiatives in this direction, when designing the knowledge ontology present in their model of adaptive on-line education system: The IEEE Learning Objects Metadata (LOM) and the Multibook project. The IEEE LOM Model specifies the syntax and semantics of learning objects metadata (Fischer, 2001). These objects can be considered concepts in an N-dimensional map, in which a new dimension is defined when a new type of object is used (examples of objects include multimedia content, instructional content, instructional software, and so on).

Multibook is an adaptive hypermedia system used to teach multimedia technology (Multibook, 2004). Multibook’s knowledge base works with two different spaces: the ConceptSpace and the MediaBrickSpace. The ConceptSpace is an ontology, in which each concept is defined in terms of keywords that are used to sketch a lesson. The MediaBrickSpace contains the actual content to be displayed (text, images, audio, video, animation) (Fisher, 2001). The elements in these two spaces are connected via binary relations similar to the ones found in

CMs. These semantic relations are not intended to be complete and need to be redesigned in case the model is used in another domain.

Although these initiatives are not directly connected to the concept mapping process, they list some very common linking phrases found in CMs. A more complete categorization of binary relations, collected directly from linking phrases used by learners in CMs, was defined by Kathleen Fisher (Jonassen, 1996), resulting from her long experience with semantic networks, using the SemNet software (Fisher, 1992). This categorization is the basis of our grammar, because it is a fairly comprehensive list of link types that may be used to connect concepts during the mapping process. The resulting EBNF grammar is capable of determining the possible dimensions of linking phrases in propositions. The grammar itself can be graphically seen as a CM, as illustrated in Figure 6.

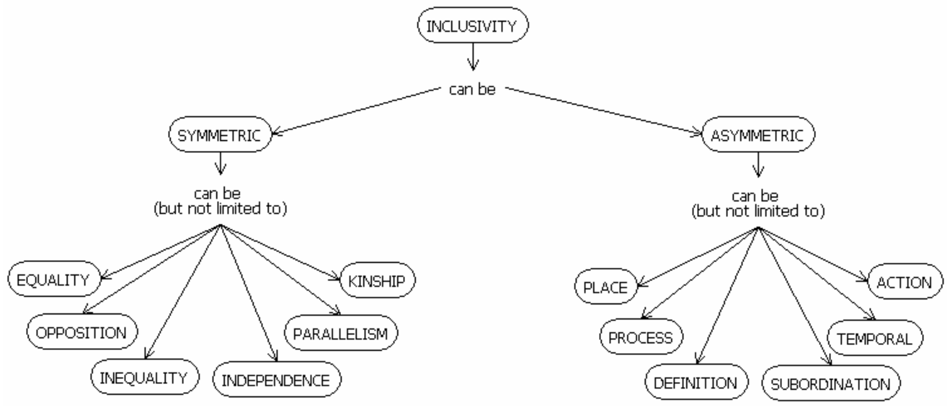

Figure 6. CM about the inclusivity grammar

Each of the non-terminal symbols in the grammar (concepts in Figure 6) can be determined in terms of terminal symbols that encompass its dimension, or can be further elaborated, by the use of recursive non-terminal symbols. An example is provided in Table 1, in which the non-terminal **Definition** is detailed.

Symbol	Type
Analytical	Non-terminal
Synthetical	Non-terminal
'is described by'	Terminal
'is defined by'	Terminal
'describes'	Terminal
'defines'	Terminal

Table 1. Description of the non-terminal Definition

According to the description above, excerpts of the EBNF grammar for inclusivity can be seen in Figure 7. This grammar is in constant evolution and is by no means complete, because it is not possible to completely describe all the permissible relations in a CM. It is, however, an attempt to classify the most commonly used binary relations, yet allowing for improvements and extensions (depending on the domain under analysis). Although the grammar alone can be the basis of an automated CM parser, it can also have its terminal symbols connected to a lexicon capable of linking words with synonyms, like the **synsets** in WordNet (Fellbaum, 1998). As a result, the capabilities of the parser would be greatly enhanced. It would be able to analyze the expressions in the grammar and also various synonymous expressions in the lexicon.

```
Inclusivity= (Symmetric | Asymmetric);
    Symmetric= Opposition | Equality | Inequality | Kinship | Independence | Parallelism;
        Opposition=(Logical | Physical);
            Logical='does the opposite of' | 'is opposite of' | 'is contrary' | 'has antonym' | 'is opposed
            to';
            Physical='is opposite';
        Equality=(Logical |Physical);
            Logical='equals' | 'is same as' | 'has synonym';
            Physical='is in same place';
    (…)
    Asymmetric=Definition | Subordination | Place | Temporal | Action | Process;
        Definition=Analytical | Synthetical | 'is described by' | 'is defined by'| 'is denoted by' |
```

‘describes’ | ‘defines’| ‘denotes’;
Analytical=(Partition | Characterization);
Partition=(Aggregation | Composition | Organization);
Aggregation= (Temporal | Non-Temporal);
Temporal= ‘has step’ | ‘has stage | ‘is step of’ | ‘is stage of’ ;
Non-Temporal=‘has part’ | ‘has piece’ | ‘contains’ | ‘is part of’ | (…)
Composition=(Temporal | Non-Temporal);
Temporal= ‘has’ | ‘has step’ | ‘has stage | ‘is step of’ | ‘is stage of’ ;
Non-Temporal= ‘has part’ | ‘has piece’ | ‘contains’ | ‘is part of’ | (…)
Organization= ‘is organized in’;
(…)

Figure 6. Excerpts of the EBNF Grammar for Inclusivity (indentation is used to facilitate reading)

Some points about the grammar are important: 1) other classifications are possible and may depend on the domain under analysis (our attempt is to classify the most generic relations); 2) although the grammar is self-explanatory in its majority, it may be confusing at first to discern among Aggregation, Composition, and Organization. Aggregation is a whole-part dimension in which the whole still exists when deprived of one of its parts. Composition is a whole-part dimension in which the whole does not exist by itself when deprived of one of its parts. Organization does not describe elementary units of a whole, but rather organizational units, that exist only for the sake of explaining or organizing the whole; 3) expressions like ‘causes’ and ‘is caused by’ permeate the grammar. Although they differ from each other (one is in the active voice, the other is in the passive voice), one can be easily transformed into the other. Since they represent the same semantic notion, we decided to classify them in the same super-type, although more detailed grammars could separate them.

4 Scenario of Use: CMTool

The categorization of linking phrases in the form described in this article is being implemented in the CMTool environment (Rocha & Favero, 2004). Figure 7 presents CMTool’s block diagram, whose architecture includes five modules and a repository. The ontology, the genetic algorithm (GA) and the assessor work together to produce an assessment of a CM. The CM editor implements a visual language sufficiently expressive to draw CMs that can be analyzed automatically without risk of ambiguity. The administrator controls the access to the environment. The repository stores CMs, ontologies and user information.

CMTool considers learning assessment as an adaptive and evolutionary problem. Therefore, instead of comparing the learner’s CM (CM_{ap}) to a reference CM (CM_r), the environment contrasts CM_{ap} with a collection of CMs generated by the GA for the learning task underway (the collection is a population and each CM in the population is an individual). Based on a function centered in the categorization of linking phrases, the assessor calculates the semantic distance (proximity) from CM_{ap} to each of the individuals in the population. This is a process that enriches learning assessment, as it is possible to present to the learner all the possible alternatives to CM_{ap}, according to what is registered in the learning task ontology. An example of this process is summarized below. For a more detailed discussion on how CMTool works, refer to Rocha et al. (2004).

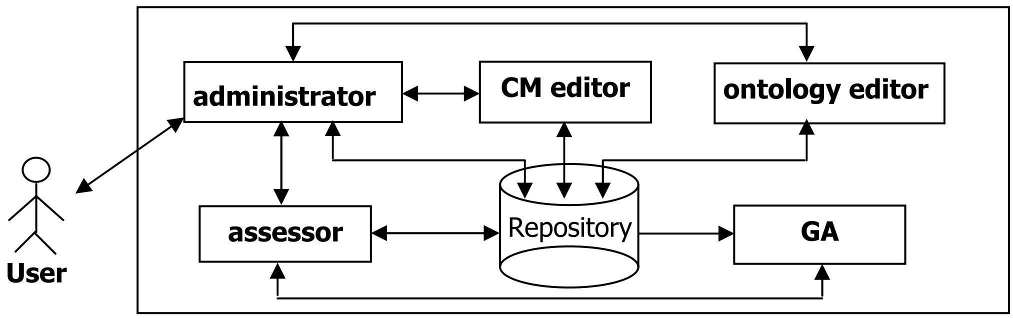

Figure 7. Architecture of the CMTool environment

Consider the learning task is to study *“the water cycle”* and consider that the domain ontology for this task – kept in the repository and entered via the ontology editor – can be summarized as follows: 1) concepts: WATER CYCLE, EVAPORATION, CONDENSATION, PRECIPITATION; 2) relations: a) temporal type: ‘has phase’,‘has stage’,‘precedes’,‘comes before’,‘is phase in’,‘is stage of’,‘succeeds’,‘comes next’; 3) binary relations: <WATER CYCLE,r_1,CONDENSATION>, <WATER CYCLE,r_2,EVAPORATION>, <WATER CYCLE,

r_3,PRECIPITATION>, <EVAPORATION,r_4,CONDENSATION>, <CONDENSATION,r_5,PRECIPITATION>; 4) values of r_1, r_2, r_3: 'has phase', 'has stage'; 5) values of r_4, r_5: 'precedes', 'comes before'.

With this information we can determine all the valid propositions in this context, as well as the semantic distances between them, as follows. Valid propositions: $\{p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8, p_9, p_{10}\}$ = {<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has stage, CONDENSATION>, <WATER CYCLE, has phase, EVAPORATION>, <WATER CYCLE, has stage, EVAPORATION>, <WATER CYCLE, has phase, PRECIPITATION>, <WATER CYCLE, has stage, PRECIPITATION>, <EVAPORATION, precedes, CONDENSATION>, <EVAPORATIION, comes before, CONDENSATION>, <CONDENSATION, precedes, PRECIPITATION>, <CONDENSATION, comes before, PRECIPITATION>}; semantic distances between the propositions: a) $d_p(p_1, p_2) = d_p(p_3, p_4) = d_p(p_5, p_6) = d_p(p_7, p_8) = d_p(p_9, p_{10}) = 0$; b) $d_p(p_1, p_i) = \infty, 1 \leq i \leq 10, i \neq 2$; c) $d_p(p_3, p_i) = \infty, 1 \leq i \leq 10, i \neq 4$; d) $d_p(p_5, p_i) = \infty, 1 \leq i \leq 10, i \neq 6$; e) $d_p(p_7, p_i) = \infty, 1 \leq i \leq 10, i \neq 8$; f) $d_p(p_9, p_i) = \infty, 1 \leq i \leq 10, i \neq 10$.

Semantic distances between propositions are symmetric, i.e. ($d_p(p_i, p_j) = d_p(p_j, p_i)$). The distance $d_p(p_i, p_j) = 0$ means that p_i and p_j are semantically equivalent, while $d_p(p_i, p_j) = \infty$ means that p_i and p_j are semantically incomparable. The function implemented also admits $d_p(p_i, p_j) = 1$ when p_i and p_j are semantically approximate (same binary relation, but the value assigned to the relation is not meaningful in the context, according to the ontology). The semantic distance between CMs is defined as a function of the semantic distances of their comparable propositions (the ones that contain the same concepts). For example, d_p(<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has stage, CONDENSATION>) = 0, because <has phase> and <has stage> are both included in the **Temporal** type that describes the relation <WATER CYCLE, r_1, CONDENSATION>. Considering CM_1 = {<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has phase, EVAPORATION>} and CM_2 = {<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has stage, EVAPORATION>}, $d_m(CM_1, CM_2) = 0$, because max((d_p(<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has phase, EVAPORATION>), d_p(<WATER CYCLE, has phase, CONDENSATION>, <WATER CYCLE, has stage, EVAPORATION>)) = 0, where *max* is the biggest value in the argument list of the function.

5 Conclusions

In this article we show how to automatically compute linking phrases, analyzing the nature of inclusivity in CMs. The objective of the study is to define a disambiguator mechanism capable of interpreting automatically, univocally, the binary relations between concepts in a CM. We have used the EBNF notation to formalize a free-context grammar that describes a hierarchy based on the semantic inclusion concept.

The meaningful learning theory is a viable form of constructivism if it is mediated by a tool like concept map. Nevertheless, constructivist learning is inherently adaptive (idiosyncratic) and evolutionary. It is adaptive because there are several ways in which humans can construct the same knowledge (Novak, 1998) and it is evolutionary because new knowledge, learned meaningfully, is always anchored in previous knowledge (Ausubel, 2000).

The experiments we have carried out at our education institution have showed us that we need more than a reference CM (one constructed by a specialist, for example) to assess learners' CMs, considering this idiosyncratic character of meaningful learning. That is the reason why we have concentrated on mechanisms capable of generating collections of CMs to represent this variability in learning, and capable of storing the knowledge that can be mapped in the context of a learning task. Our proposal of CM assessment involves the use of domain ontologies and machine learning via genetic algorithms (GAs). In CMTool (Section 4), ontologies are mechanisms that store knowledge in the form of concepts and binary relations between them. They also store the inclusivity grammar described in this paper, which is used by the GA to analyze and determine the meaning of generic binary relations. The inclusivity grammar can also be used to compare and contrast CMs. Our first version of this grammar, developed in Prolog, is currently being converted to Java.

Ausubel (2000) says that the cognitive structure is characterized by factors (or variables) that need to be enhanced for the improvement of education. Therefore, more research needs to be carried out to predict or measure stability, clarity, and discriminability of the cognitive structure. Our results are a step towards this direction.

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Concept Maps: Theory, Methodology, Technology
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A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

A NEW APPROACH TO MEANINGFUL LEARNING ASSESSMENT USING CONCEPT MAPS: ONTOLOGIES AND GENETIC ALGORITHMS

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Abstract. In this article we discuss the use of concept maps (CMs) in learning assessment. As an alternative to the comparison of the learner's CM with the teacher's CM, in order to certify what is right or wrong or to attribute a grade, we present a new approach to assess CMs: we consider learning assessment as an adaptive and evolutionary problem and we show how to use ontologies and machine learning, through genetic algorithms (GAs), to assess CMs. The ontologies we use store knowledge, in the form of concepts and propositions, and functions to measure the semantic distance between CMs. The GA, using the ontology, generates the search space (collections of CMs) used to show learners the alternatives to their possible faults when learning concepts and propositions. The complete assessment of a CM includes the analysis of its hierarchical structure, the recognition of learning types, and the analysis of semantic similarity with the CMs of the search space. We also show the actions executed by the GA to construct the CMs of the search space and the concepts present in the ontology and ignored by the learner.

1 Introduction

Concept mapping is a process of knowledge construction. The concept maps (CMs) that result from this process represent significant combinations between concepts in the form of propositions – a concept is a regularity perceived in objects, events, situations or properties (Novak, 1998, p.22), or concepts are the abstracted criterial attributes that are common to a given category of objects, facts, or phenomena (Ausubel, 2000, p.2). A proposition is a combination of two or more concepts mediated by linking words (Novak, 1998, p.32).

The linking words that appear in each proposition denote *values* assigned to binary relations that exist between concepts combined in a proposition. They can be organized in hierarchies of types (super-types) considered as metadata (Fischer, 2001). For example, in the propositions <TREE has ROOT> and <TREE feeds through ROOT> the linking words <has> and <feeds through> can be seen as values of the super-types **partition** and **process.**

CMs are established on three fundamental theoretical principles: hierarchical structure, progressive differentiation, and integrative reconciliation (Novak & Gowin, 1999). The hierarchical structure of a CM is based on the concept of *inclusion*, that is, each concept put in a CM has a level of inclusion relative to the other concepts already in the map. Therefore, inclusion is used to classify the concepts of a CM and is fundamental for the construction of meanings (Costa Jr et al., 2004). Figure 1 shows a CM as proposed by Novak. <HUMAN LEARNING> is the concept of higher degree of inclusion and classifies the concepts <COGNITIVE LEARNING>, <AFFECTIVE LEARNING>, and <PSYCHOMOTOR LEARNING>, according to a **characteristic** (attributes) dimension.

Progressive differentiation is the process of meaningful learning in which learners increase the degree of elaboration of a concept as they increase their understanding about it (Ausubel, 2000). In order to detect progressive differentiation in a CM, it is necessary to observe if the concept object of the learning classifies other concepts in one or more dimensions. In the example illustrated in Figure 1, the concept <COGNITIVE LEARNING> is progressively differentiated.

Integrative reconciliation is the meaningful learning in which the learner discerns relations between concepts not initially categorized. There are two types of integrative reconciliation learning: *superordinate integrative reconciliation* and *combinatorial learning*. Superordinate integrative reconciliation occurs when the learner identifies a more inclusive concept, not initially present in the CM, which includes concepts already learned and represented in the map. In order to observe superordinate integrative reconciliation, it may be necessary to observe two distinct moments of the learning represented in the CMs and to have specific graphical notation for it (see Figure 2).

Combinatorial learning occurs when the learner, without identifying a more inclusive concept, can discern the need of relating concepts placed in different branches of the same CM. Figure 2 presents two situations of integrative reconciliation: in Figure 2(a), the concept <KNOWLEDGE> superordinates <CONCEPTS> and <PROPOSITIONS>, and these two combine to express how prepositions are formed.

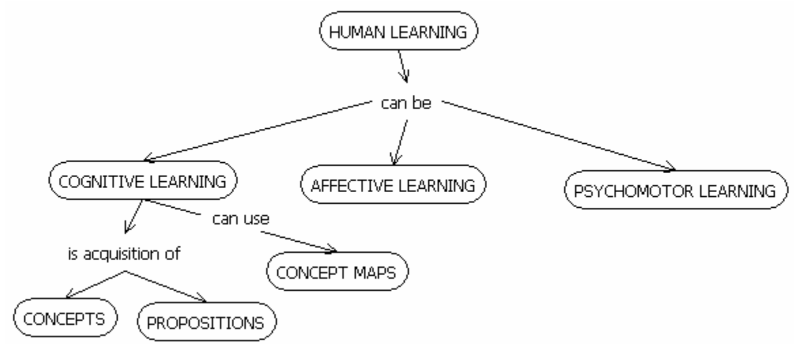

Figure 1. Concept Map about HUMAN LEARNING

Figure 2(b) differs from Figure 2(a) in an important point: the proposition notation with solid lines informs that the type of learning in Figure 2(a) is *progressive differentiation* while the notation with dashed lines in Figure 2(b) informs that the learning type is integrative reconciliation.

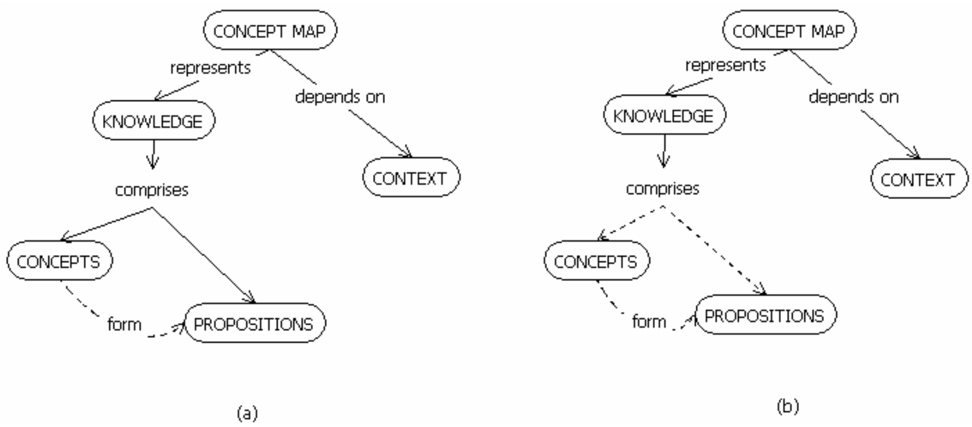

Figure 2. Combinatorial integrative reconciliation and superordinate integrative reconciliation

Assessing learning in an educational context can be seen as the process of characterizing what a student knows (Turns et. al., 2000). Using CMs to assess learning is important because their structure contains the cognitive elements considered evidence of learning in Ausubel and Novak's theory: concepts, hierarchy of concepts, propositions, progressive differentiation, combinatorial and superordinate integrative reconciliation. However, constructivist learning can lead to many different ways of constructing the same knowledge. For example, innumerous types of relations can exist between <PLANT>, <ROOT>, <STEM>, <LEAF>, <FRUIT>, <SEED>, and <FLOWER>. Learning assessment of these concepts based on a single reference MC would be very inaccurate, because a single CM is not capable of encompassing all the potential learning situations involved. On the other hand, the task of constructing reference CMs capable of coping with this process of individual assessment would be overwhelming. An alternative to face this problem is to provide the teacher with the possibility of creating domain ontologies with the concepts and their relations in the context of a learning task. A complementary mechanism could then simulate all the possible learning processes and represent them as collections of CMs. This is the fundamental idea why we chose to use genetic algorithms as the mechanism capable of producing these collections.

In this article we present the CMTool learning assessment system (Rocha & Favero, 2004). CMTool's main objective is to provide support to the practical application of Ausubel and Novak's theory in classroom, focusing on the assessment of learning. The assessment process in CMTool is based on: (i) a domain ontology that stores concepts, binary relations, linking words, and the function to measure semantic distances between concepts, propositions and CMs; (ii) a genetic algorithm (GA) that, based on the ontology data, generates collections of CMs (search space) for the accomplishment of the assessment; (iii) an assessor that uses the search space generated by the GA and the ontology to detect evidences of learning in the learner's CM.

The article contains five sections, including this introduction. In section 2, a general description of CMTool is presented, including the assessment system. In section 3, we present an example of assessment of a simple CM. Section 4 presents research related to our work. We conclude the article in section 5.

2 The CMTool Environment

Figure 3 presents CMTool's block diagram, which encompasses five modules: administrator; concept map editor; ontology editor; learning assessor; genetic algorithm (GA); and a repository (user information, instances of search spaces generated by the GA, ontologies, and instances of CMs of users registered in the environment).

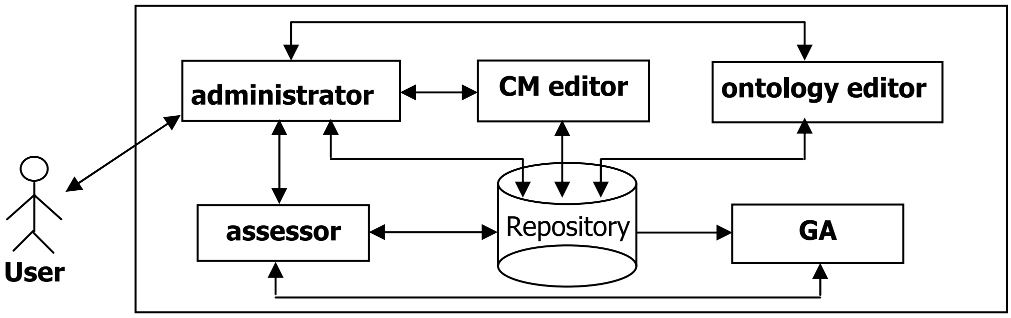

Figure 3. Architecture of the CMTool environment

The administrator is responsible for controlling environment access (registration and identification of users, for example), and for allowing access to the editors and to the assessor. The registration system of the administrator assigns to the users the right of accessing specific functionalities of the environment. For example, teachers registered in the environment can access the CM editor, the ontology editor, and the assessor. Students, on the other hand, are able to access only the CM editor. The CM editor implements a visual language for constructing CMs in compliance with the principles of Ausubel and Novak's meaningful learning theory. The module provides a graphical interface composed of a drawing panel and a toolbar with the metasigns and the functionalities necessary to draw, edit, save, and recover concept maps. Table 1 presents some of the signs of the CM editor.

Sign	Semantics
(PLATYPUS)	Used to represent generic concepts (e.g., PLATYPUS)
[PHILLY]	Used to represent examples of concepts (e.g., PHILLY)
— link-word →	Used to represent hierarchies and progressive differentiation
- - - - link-word - - >	Used to represent hierarchies and integrative reconciliation
<<>>	Used to write grouped propositions (conjunction)

Table 1. CMTool environment signs

In order to write concepts, the visual language provides two symbols: a rectangle with rounded corners and a rectangle with straight corners. The first one is used to represent generic concepts, while the second one is used to represent examples. The lines of the arrows that link concepts can be dashed or solid, straight or curved. The style of the line (dashed or solid) is used to clarify the type of learning (progressive differentiation or integrative reconciliation), while the form of the line (straight or curved) is only a convenience for the drawing process. The *and* conjunction is a symbol without graphical representation. It is used to compact the writing of propositions starting in the same concept, when they use the same linking word. In Figure 2(a) the linking word *comprises* is written on an *and* conjunction. In this case, the reading of the propositions starting in <KNOWLEDGE> could be: <<KNOWLEDGE comprises CONCEPTS> and <KNOWLEDGE comprises PROPOSITIONS>> or <<KNOWLEDGE comprises CONCEPTS and PROPOSITIONS>>.

Examples are elements that must be distinguishable in a CM, either to help grading it, or to detect more precise understanding during the learning process (Novak & Gowin, 1999, p.53). That is the reason why some CM editors use more than one symbol to represent concepts (for example, see Cunha & Fernandes, 2002). In CMTool, the graphic symbols of the environment are part of a visual language (not detailed in this paper), with syntax and semantics. As in all languages, some users will be less experienced than others. Consequently, we do not expect young learners to use it in all its potential. Nevertheless, our experience with graduate and undergraduate students showed us that progressive differentiation and integrative reconciliation, for example, can occur consciously during learning. As a result, it is necessary to distinguish them graphically, from an external point of view, and computationally, from an internal point of view.

The ontology editor is used to construct and store in the repository the domain ontologies that correspond to the learning tasks used to organize the teaching of the topics of a discipline. An ontology is a catalogue of *types* *of things* for a determined domain of interest D from the perspective of a language L constructed with the purpose of describing D (Sowa, 2000). In CMTool, the types in the ontology represent concepts and linking words that can be described by the visual language of the environment.

The functioning of the GA is centered in the ontology. Genetic algorithms are blind search algorithms whose purpose is to find a collection of possible results for a given problem. Each result in the collection is an individual and the collection is a population (Zbigniew & Fogel, 2002). In CMTool, a population is a set of CMs with characteristics similar to those of a CM presented as input to the algorithm. Each CM in the generated population has its history of construction, which registers the meaningful learning simulation process used by the GA during the construction of the associated CM.

The assessor uses the results produced by the GA and the ontology to produce a complete assessment of the learning of a student or group of students. The assessor applied to a single CM can inform: (i) valid propositions; (ii) valid concept hierarchies; (iii) valid integrative reconciliations; (iv) valid progressive differentiations; (v) examples; (vi) the relation of semantic proximity between the CM constructed by the learner and those generated by the GA; and (vii) the collection of actions that were used by the GA to generate the population. The assessor applied to two or more CMs can detect if there was evolution in the learning.

The repository stores CMs, ontologies, assessments and populations of CMs generated by the GA. The ontologies are generated by the ontology editor. These ontologies will be read by the GA in order to generate the populations of CMs, and also by the assessor, that obtains the result of the functions that calculate semantic distances. A population of CMs is stored in the repository by the assessor after the accomplishment of an assessment. Each population stored in the repository is identified by the ontology and the concepts used to build it. When receiving a CM to analyze, the assessor examines the repository in search of a population that can be used in the current analysis. If the assessor finds a population, it recovers and uses it. If not, it activates the GA to generate the desired population. The assessor also records in the repository the result of each assessment accomplished.

3 An assessment example

In this section we present an example that shows the functioning of the GA and of the assessor of the environment. The example is related to the learning task *What it is a plant?*

3.1 Data stored in the ontology

For this learning task, the ontology has the following data:

1. concepts: {PLANT, ROOT, STEM, LEAF};
2. relations: partition type: {has part, contains, is example, is instance};
3. binary relations: {<PLANT, r_1, ROOT>, <PLANT, r_2, STEM>, <PLANT, r_3, LEAF>};
4. values of r_1, r_2, r_3: {has part, contains}.

With this information it is possible to determine all the valid propositions for this context, as well as the semantic distances between them, as follows. Valid propositions: $\{p_1, p_2, p_3, p_4, p_5, p_6\}$ = {<PLANT, has part, ROOT>, <PLANT, contains, ROOT>, <PLANT, has part, STEM>, <PLANT, contains, STEM>, <PLANT, has part, LEAF>, <PLANT, contains, LEAF>}; semantic distances between the propositions: $d_p(p_1,p_2) = d_p(p_3,p_4) = d_p(p_5,p_6) = 0$; $d_p(p_1,p_i) = \infty, 3 \leq i \leq 6$; $d_p(p_2,p_i) = \infty, 3 \leq i \leq 6$.

The semantic distance between propositions is symmetric ($d_p(p_i,p_j) = d_p(p_j,p_i)$). The distance $d_p(p_i,p_j) = 0$ means that the propositions p_i e p_j are semantically equivalent, while $d_p(p_i,p_j) = \infty$ means that the propositions p_i e p_j are semantically incomparable. The function implemented also admits $d_p(p_i,p_j) = 1$ for semantically similar propositions (same type of binary relation, but the value assigned to the relation is not meaningful in the context of the learning task, according to the ontology). The semantic distance between CMs is defined as a function of the semantic distance of the propositions in the maps that can be compared (encompassing the same concepts). For example, d_p(<PLANT, has part, ROOT>,<PLANT, contains, ROOT>) = 0, because <has part> and <contains> are equally included in the **partition** type describing the relation <PLANT, r_1, ROOT>. On the other hand, d_p(<PLANT, has part, ROOT>,<PLANT, is instance, ROOT>) = 1 and d_p(<PLANT, has part, ROOT>,<PLANT, has characteristic, ROOT>) = ∞. Given CM_1 = {<PLANT, has part, ROOT>,<PLANT, has part, STEM>} and CM_2 = {<PLANT, has part, ROOT>,<PLANT, contains, STEM>}, $d_m(CM_1, CM_2) = 0$, because max((d_p(<PLANT, has part, ROOT>,<PLANT, has part, ROOT>), d_p(<PLANT, has part, STEM>,<PLANT, contains, STEM>)) = 0, where *max* is the biggest value in the argument list of the function.

3.2 Actions of the GA

Figure 4 represents actions of the GA. Based on the CM of the learner submitted to the assessor (Figure 4(a)) and on the ontology for the learning task underway, the GA determines the initial population of CMs (Figure 4(b)). Afterwards, the GA selects in the current population the individuals better fitted to be the parents of the next population (in the example, all the individuals are selected because they all have the same fitness value). It then submits these individuals to the genetic operators of crossing and mutation (Figures 4(c) and 4(d)). The new population is formed by the ancestors and their descendants. The algorithm repeats this procedure until n populations (n is configurable) are generated or all the individuals of a population reach a satisfactory fitness value. Figure 4(e) represents the final population generated by the GA for the learning session in progress.

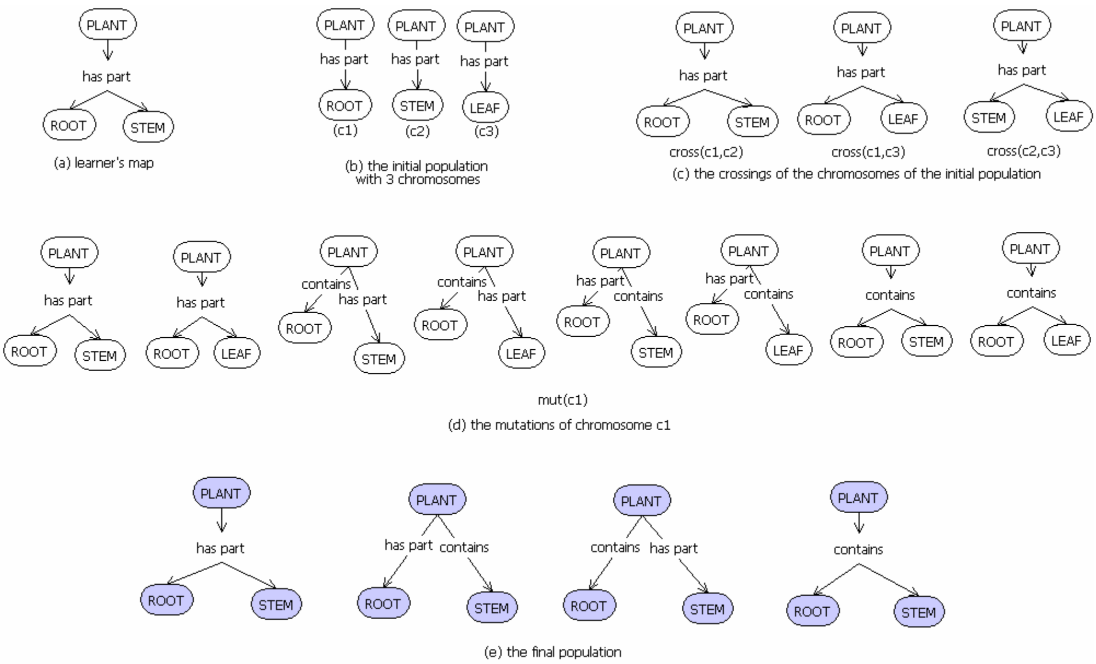

Figure 4. Actions of the GA

The GA is based on axioms that describe how to form its basic elements and genetic operators. The basic elements are *base*, *gene*, *chromosome*, and *population*, and the genetic operators are *crossing* and *mutation*. The chromosomes (CMs) of a new population are those with fitness equal or greater than the average fitness of the previous population. The average fitness of a population is the arithmetic mean of the fitness of its chromosomes. The fitness of a chromosome is the weighted sum of the fitness of each of its genes, and the fitness of a gene is calculated based on the binary relation it expresses. The taxonomy that allows assigning values to binary relations is described in Costa Jr et al. (2004). For example, considering the genes g_1 = <PLANT, has part, LEAF> and g_2 = <PLANT, has part, ROOT> (see Figure 4(b)), their fitness equals 2, because both belong to the ontology. The weight of g_1 is 1, because only the concept <PLANT> exists in CM_{ap} (see Figure 4(a)), while the weight of g_2 is 2, because the concepts <PLANT> and <ROOT> exist in CM_{ap}. Therefore, the chromosome <<PLANT, has part, LEAF>, <PLANT, has part, ROOT>> has a fitness degree of 6 (2*1 + 2*2). The weights are the mechanism used to privilege the concepts present in CM_{ap}. The complete specification of the GA used in CMTool is in Rocha et al. (2004).

3.3 Assessment Results

Figure 5 presents the results of an assessment accomplished by CMTool. The results are organized in four parts: (a) Hierarchical structure and learning types demonstrated; (b) Semantic similarity between the assessed CM and the CMs generated by the GA; (c) Actions necessary for the reconstruction of the generated CMs; (d) Omissions in the assessed CM.

Assessment Results

a) Hierarchical structure and learning types

01. CM Assessed: CM_{ap} = {<PLANT,has part,ROOT>,<PLANT,has part,STEM>}
    Concepts: {PLANT,ROOT,STEM}
    Propositions: {<PLANT,has part, ROOT>(p_1),<PLANT,has part,STEM>(p_2)}
02. Hierarchical level:
    Level 0: PLANT
    Level 1: ROOT,STEM
03. Valid hierarchies(1): {<PLANT,partition,ROOT>,<PLANT,partition,STEM>}
04. Invalid hierarchies(0): {}
05. Valid propositions(2): {<PLANT,has part,ROOT>,<PLANT,has part,STEM>}
06. Invalid propositions(0): {}
07. Valid integrative reconciliations(0): {}
08. Invalid integrative reconciliations(0): {}
09. Valid progressive differentiations(1): {<<PLANT>,partition,<ROOT,STEM>>}
10. Invalid progressive differentiations(0): {}
11. Examples(0): {}

b) Semantic similarity

01. Population generated by the GA(4):
    Concepts {PLANT,ROOT,STEM}
    Ontology: EN250-01;
    CM_1 = <<PLANT,has part,ROOT>(p_3),<PLANT,has part,STEM>(p_4)>
    CM_2 = <<PLANT,has part,ROOT>(p_5),<PLANT,contains,STEM>(p_6)>
    CM_3 = <<PLANT,contains,ROOT>(p_7),<PLANT,has part,STEM>(p_8)>
    CM_4 = <<PLANT,contains,ROOT>(p_9),<PLANT,contains,STEM>(p_{10})>
02. Calculation of semantic distances:
    CM_{ap} versus CM_1:
        $d_m(CM_{ap},CM_1) = 0$; (CM_{ap} and CM_1 have the same meaning)
    CM_{ap} versus CM_2:
        $d_m(CM_{ap},CM_2) = 0$; (CM_{ap} and CM_2 have the same meaning)
    CM_{ap} versus CM_3:
        $d_m(CM_{ap},CM_3) = 0$; (CM_{ap} and CM_3 have the same meaning)
    CM_{ap} versus CM_4:
        $d_m(CM_{ap},CM_4) = 0$; (CM_{ap} and CM_4 have the same meaning)

c) Actions for the reconstruction of the generated CMs

CM_1:
    form the propositions: {p_3, p_4};
    combine: p_3, p_4 (differentiate PLANT progressively)
CM_2:
    form the propositions: { p_5, p_6};
    combine: p_5, p_6 (differentiate PLANT progressively)
CM_3:
    form the propositions: { p_7, p_8};
    combine: p_7, p_8 (differentiate PLANT progressively)
CM_4:
    form the propositions: { p_9, p_{10}};
    combine: p_9, p_{10} (differentiate PLANT progressively)

d) Ontology concepts absent in CM_{ap}:

{LEAF}

Figura 5. Results of a CM assessment accomplished by CMTool

Part (a) reports if the concepts used in the CM submitted for assessment (CM_{ap}) are related to the learning task underway, as registered in the ontology used, and if the learner's propositions are valid in this context. The inclusion level of each concept is verified with the help of a semantic reading by inclusion level of CM_{ap} (Rocha & Favero, 2004). The result of this reading of CM_{ap} is compared to the result of an identical reading performed on the CMs generated by the GA. If the results match, the assessor certifies the correction of the hierarchical levels present in CM_{ap}. The assessor also verifies if the inclusion of the concepts is made through correct classification types. For example, in <PLANT, partition, ROOT> <PLANT> classifies <ROOT> based on the partition type (whole-part), which is confirmed by the ontology. Other results of part (a) can be seen in Figure 5.

Part (b) presents the semantic comparison of CM_{ap} to the final population of CMs generated by the GA. The objective is to present to the learner other valid forms of mapping the knowledge represented in the ontology of the learning task underway. The assessor calculates the semantic distance between CM_{ap} and each one of the CMs in the final population generated by the GA. If any of the calculated values is different from zero, detailed information containing the possible alternatives to the identified misconception are presented to the learner.

Part (c) details the actions that were taken by the GA to construct the population of CMs presented in part (b). The objective is to show to the learner how to construct forms of knowledge representation alternative to his/her own (presented in part (a)). Finally, part (d) presents the list of concepts that, although present in the ontology used, were not mapped by the learner. The list may indicate the need for reinforcement of specific topics of the discipline.

4 Related research

The computerized treatment of CMs as support to **meaningful learning** has been the focus of many research projects. Concerning map editors, we have found excellent tools like CmapTools (Cañas et al., 1999) and LifeMap (http://www.robertabrams.net/conceptmap/lifemaphome.html). They provide several possibilities of construction and sharing of knowledge via CMs.

Concerning learning assessment using CMs, some ongoing research projects need to be mentioned. Araújo et al. (2003) analyze the work overload on the teacher resulting from the use of CMs in the process of learning and propose an automated way to minimize this problem. Their assessment proposal is based on the comparison between the learner's CM and the teacher's CM. Cunha & Fernandes (2002) propose a cooperative environment to intermediate the synchronous interaction among learners and the learning facilitator. In this environment, designed to run on the Web, the assessment is based on the comparison between a reference CM and the learner's CM. Cabral & Giraffa (2002) also propose learning assessment based on the comparison between the learner's CM and the teacher's CM. Chung et al. (2002) developed a prototype in which learning assessment is based on the comparison with CMs constructed by specialists. McGriff (2001) describes how to use CMs to measure a learner's cognitive structure with the help of computational procedures. Turns et al. (2000) proposes the use of CMs to assess learning based on the grading of different characteristics of the map, such as width, depth, and connectivity. The comparison with a specialist's CM is also used to verify the number of valid and invalid propositions, as well as the presence or absence of concepts and relations considered critical.

Our research is innovative because it introduces the idea of using GAs and ontologies in the process of learning assessment.

5 Conclusions

In this article we describe the architecture of the CMTool environment, a tool developed to support the meaningful learning theory in classroom, focusing on learning assessment. As shown in section 4, most of the research about assessment using CMs compares the learner's CM to a reference CM, which appears to us to be unsatisfactory for constructivist learning.

Based on several experiments carried out in our education institution, we have understood that it was necessary to advance a little more in some directions to reach the objective of assessing precisely the learning types and cognitive styles used to learn. This is a difficult task as the learning process is personal (idiosyncratic) and the assessment based on the comparison between a learner's CM and a CM drawn by a specialist ends up reproducing the positivistic logic of behaviorism (Novak, 1998, p. 49).

Instead of using this approach, our proposal to assess a CM involves the use of ontologies and machine learning (through genetic algorithms – GAs). Ontologies can describe knowledge domains, but not the types of meaningful learning. On the other hand, the genealogic operators in a GA are capable of, based on an ontology, simulating the construction of the learning situations known as progressive differentiation and integrative reconciliation. Additionally, the assessor component, using a function stored in the ontology, can measure the semantic distance between CMs. This is important because the environment can present alternative learning situations to the student, as well as emphasize possible misconceptions. As future research, we are studying the use of the assessor in mining learning styles in collections of CMs. The objective is to identify dominant learning styles (progressive differentiation or integrative reconciliation). This is an important functionality, because it allows classifying students under cognitive preferences and offering personalized aid during the learning process.

Concerning the GA, two aspects need further consideration: the quantity of produced material and scalability. The dimension of the search space is a good measure of the quantity of material produced by the GA. It is proportional to the richness of the ontology and to the characteristics of CM_{ap}. In some situations, the search space may be greater than necessary, considering the learning task. Because of this, we are currently developing mechanisms capable of identifying and extracting significant samples of the search space. We have developed an artificial neural network (not described in this paper) capable of recognizing some semantic patterns in CMs (meronymy, holonymy, hipernymy, hyponymy, synonymy, and exemplification). The next step is to increase the quantity of recognizable patterns and incorporate this mechanism in CMTool. Concerning scalability, we have tested medium-sized ontologies (up to 100 binary relations) and verified that the GA converges quickly, if these relations are mapped up to 5 values. Once learners' CMs usually have 20 to 30 binary relations, the performance of the GA can be considered satisfactory.

Ausubel (2000) says that the cognitive structure is characterized by factors (or variables) that need to be enhanced for the improvement of education. Therefore, more research needs to be carried out to predict or measure stability, clarity and discriminability of the cognitive structure. Our results are a step towards this direction.

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USING CONCEPT MAPS WITH ADULT STUDENTS IN HIGHER EDUCATION

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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 adult graduate students in the context of higher education. Two groups of students were taught to use concept mapping as a constructivist learning strategy and then were followed over the course of a year to determine the impact this strategy had on their learning. Results indicate that adult graduate students became more aware of their own learning processes, changed their learning strategies and articulated changes in their thinking. Implications for teaching and learning in higher education are drawn.

1 Introduction and Problem Statement

Adult graduate students often enter higher education programs relying on learning strategies that have worked well for them in the past (Merriam & Caffarella, 1999). These previous learning strategies often include rote learning, passive learning, memorization and recall of facts. Assisting adult graduate students to broaden their learning strategies is a major factor contributing to their academic success in higher education (Gibbons, 1990; Novak, 1990; Smith, 1982) and to their ability to function in the workplace. The purpose of this study was to assist adult students to enhance their learning through the application of teaching strategies that foster a constructivist approach to learning.

2 Conceptual Framework

Merriam and Caffarella (1999) define five different learning orientations including: behavioral, social, humanistic, cognitive and constructivist learning. They believe that within each of these learning orientations different assumptions exist about the nature of learning and the strategies that instructors can use to facilitate learning. Since the purpose of this study was to assist adult students to broaden their learning strategies, the constructivist learning orientation provided the overall conceptual framework for this study.

Constructivist learning has evolved to include multiple approaches and perspectives. For the purpose of this study, constructivist learning is seen as a cognitive approach that locates cognition and understanding within the individual. The most salient feature of this perspective is the "notion that learners respond to their sensory experience by building or constructing in their minds, schemas or cognitive structures which constitute the meaning and understanding of their world" (Saunders, 1992, p. 136). Constructivists, writing from this cognitive approach (Ausubel, 1986; Brunner, 1990; Novak, 1998; Piaget, 1966), express the belief that individuals create knowledge by linking new information with past experiences to create a personal process for meaning-making. Within a constructivist framework, the learner progressively differentiates concepts into more and more complex understandings and also reconciles abstract understanding with concepts garnered from previous experience (Novak, 1998). New knowledge is made meaningful by the ways in which learners establish connections among knowledge learned, previous experiences, and the context in which learners find themselves. Lambert et al. (1995) identify multiple principles of constructivist learning theory, which include the following major points: (1) knowledge and beliefs are formed within the learner, (2) learners personally imbue experiences with meaning, (3) learning activities should cause learners to gain access to their experiences, knowledge and beliefs, (4) learning is a social activity that is enhanced by shared inquiry, and (5) reflection and meta-cognition are essential aspects of constructing knowledge and meaning (pp. 17-18).

Novak (1998) operationalized constructivist learning theory by creating concept maps. "A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions," (Novak, 1984, p15). Concept maps are created with the broader, more inclusive concepts at the top of the hierarchy, connecting through linking words with other concepts that can be subsumed. This tool helps facilitate understanding of conceptual relationships and the structure of knowledge. Novak (1990) found in an analysis of multiple studies using concept maps that the technique promoted novel problem solving abilities, raised mean scores on achievement of content units, decreased students' anxiety levels and increased students' positive attitudes toward the content of study.

In order to study how constructivist strategies impact the learning of adult students, constructivist teaching strategies were employed in two graduate courses in an adult education graduate program.

3 Research Questions

In this study, adult students were taught to use concept maps. The extent to which this strategy contributed to a change in learning strategies was assessed by evaluating; (1.) the change in student concept map scores during a one-year time frame, and, (2.) adult student response's to tape-recorded interviews. The following research questions were advanced to guide this investigation.

- Do constructivist learning strategies (i.e. concept maps) contribute to the success of the adult students?
- When adult students learn to use concept maps in one course, will that learning strategy carry over to subsequent courses in which the student enrolls?
- How does the use of concept maps as a learning strategy change the thinking of adult students?
- Can concept maps transform adult students' prior learning strategies?

4 Methodology

During semester one, adult graduate students in two different courses were taught to use concept maps as an integrated part of their course work. Students developed concept maps to reflect the course readings, plan course projects, and to compare and contrast information from course discussions. Twenty-one students from these courses were randomly selected and invited to participate in this study. Following IRB approval, students gave consent to have their course work reviewed and to be interviewed twice over the academic year.

A mixed-method design using both quantitative and qualitative analysis was created for this study. The first and final concept maps created by study participants in the first semester were scored according to the scoring formula created by Novak and Gowin (1984). Reliability was established by obtaining two independent scores on each map. Inter-rater reliability was established at .80. Data analysis included calculation of group means and comparison of these means using a dependent t-test.

At the end of semester one, interviews were conducted with participants about their use of concept mapping. During the interviews, adult graduate students were asked the following questions: 1. What was it like to use concept maps as a learning strategy? 2. What did you learn while doing concept maps? 3. Where else have you used the maps since the completion of your course (if at all)? 4. How was doing the maps the same or different than other learning strategies you have used previously? 5. What did you like most/or like least about using concept maps? 6. What changes, if any, did you see in your thinking ability since using concept maps? 7. What was the most significant learning you remember from this course? 8. If you were going to describe concept mapping to another graduate student, what would you say? 9. How do you see using/or not using this learning strategy in the future?

Study participants were followed during semester two. Concept maps created by the adult graduate students at the end of semester two were scored. At the end of semester two, study participants were interviewed a second time to determine if they continued to use concept maps as a learning strategy and how that strategy impacted their thinking and learning.

Interview data was analyzed using a modified constant comparative method (Glaser & Strauss, 1967; Patton, 1990). First, all interviews were coded and themes identified using the qualitative data analysis software package N*VIVO. Then, coded data were compared from the first set of interviews to the final set of interviews by developing a system of matrices for comparison and contrast (Miles & Huberman, 1994). Finally, a summary concept map was created to synthesize the themes identified in both sets of interviews.

5 Findings

Findings from this study indicate that using concept maps impacts adult graduate student learning. The presentation of findings from this study will first focus on the changes in concept map scores and then explore student interview data related to learning with maps and the use or non-use of maps at a one-year follow-up.

5.1 Changes in Concept Map Scores

In this study concept maps were collected from participants at three separate points. In the first semester of the study, the first and final map created by the students were collected and scored. During the second semester, the final map that participants created, (if they did create a map in semester two), was collected and scored.

Data analysis (Table 1) demonstrates a group mean of 44.81 on the first concept map and 121.43 on the final concept map of the first semester, for a difference of 76.62. The t-value comparing the first to final map was –6.614 (p=.001). The data indicate a statistically significant difference between the first and final map scores of the first semester.

Table 1
Changes in Concept Map Scores over First Semester

Variable	No. of Cases	Mean	Difference
First Map of Semester 1	21	44.81	-76.62
Last Map of Semester 1	21	121.43	

P = .001 t-value = -6.614

Students were followed during the second semester of the study, to determine if they continued to use mapping as a learning strategy and if they did how the maps compared to the first semester. Data indicate that 65% of students in this study continued to use mapping into the second semester. Data indicate the mean score for the last map during semester one was 121.43 and the mean score for the last map in semester two was 120.22, for a change score of –1.21. The data indicate no significant difference between those participants mapping at the end of semester one and those mapping at the end of semester two.

Participants were also interviewed at two points during this study, at the conclusion of semester one and at the conclusion of semester two. Participants were asked during the interviews to describe their experiences with mapping as a learning strategy and to analyze how their thinking had changed or not changed through the use of mapping. Participant responses were categorized into two areas for presentation of findings: learning with maps and map use on follow-up.

5.2 Learning with Maps

Study participants indicated that to learn effectively with maps, they first had to develop the skills in map construction and to understand the mechanics of mapping. Additionally, participants reported that often their initial reaction to mapping changed and developed over the time that they used mapping.

Participants stated that part of what they enjoyed about the process of mapping was the focus on organization, analysis and understanding. Participants indicated that through the process of organizing and analyzing, they developed a more holistic picture of what they were learning. One participant stated:

> *It made you look at whatever it was you were doing in its entirety. It made you look at it as a whole. And then start breaking it down by concepts and then you would rebuild it by linking . . . You feel the knowledge building. You just feel yourself seeing things differently than before you started doing that.*

However, some participants expressed three difficulties in developing maps: finding time to complete the maps, deciding on the level of detail to include and overcoming their lack of desire to change how they learned. Participants indicated that mapping as a learning strategy was too demanding and took up too much time.

> *. . . it is just another task to do when you feel overwhelmed. It takes more time than just reading the text . . . I think it has a lot more value than what it feels like you are doing at the moment.*

Participants also expressed how difficult it was to change learning strategies that they had used in the past. Changing old habits was time-consuming and difficult for most participants in this study. One participant indicated:

> *But, I guess what I hated the most was that I had to change my thinking mode. It is before, like, well, I am just reading this information, and I am picking out what I see is in the writing or what the writer is trying to present. I guess I just didn't like the idea of changing old habits and doing things differently.*

5.2.1 Understanding One's Own Learning

A major finding of this study was that concept mapping helped adult students to understand their own learning processes. Additionally, they were able to explain that they developed their learning processes through the use of learning strategies such as linking, developing interrelationships, creating meaning schemes, and constructing knowledge. Participants reported that the maps helped them to understand how they think, to think in a broader fashion, to search out complicated relationships, and to organize information so that they remembered it in a much more comprehensive way. For example,

> *I learned a little bit about how I think based on how I put the concept map together. I learned a little bit about what challenges me, what comes easy to me. I tried to pick things to concept map that I didn't understand so that I would understand them afterwards*.

Another participant described how she developed an understanding by moving from larger concepts to smaller concepts and back again.

> *I learned to use another part of my brain. I learned also to think globally because this is going from big ideas and main ideas to smaller ideas, subtopics, so I learned to modify how I think about information. I also learned to show more linkage of information.*

Finally, participants discussed how the maps helped them apply information to their experiences and at the same time remember that information in a new way.

> *. . . instead of it being information given to me and stored away in my head, the most significant thing is that when I can apply things to my real life experience, I have a better time understanding them, better time remembering them. So to me that is a big deal.*

5.2.2 Learning Strategies

As participants came to understand their own learning processes, they also articulated of a number of learning strategies that they employed as a result of creating concept maps. Participants reported that their understanding of how to link concepts, develop interrelationships, create meaning schemes, and construct a knowledge base developed through the use of mapping.

Linking. Participants in this study were asked to describe what was their most significant lesson learned from the courses they were enrolled in during the first semester. A large percentage of the participants expressed that learning to link concepts was a new learning strategy for them and a major discovery in their own learning. The following participant expressed the value in learning to link concepts this way:

> *What I discovered in my own learning was that indeed there were connections between ideas and concepts that I hadn't picked up on just in reading the material. But it was in the diagramming of the concept map and I usually did it in two stages. My first stage was I threw enough stuff down on paper as I could [sic]. My second stage, I let it sort of sit and simmer like a pot on the back burner for awhile. Then I would come back and make some aha's, oh I see some relationships here. And that helped to open up the interconnectedness of what I had been looking at and didn't initially see.*

Another participant expressed a common theme evident in many adult learners' experiences in this study. Participants indicated that they just had not thought about the relationships between concepts previously until confronted with a learning strategy that asked them to make those connections. When asked about significant learning strategies one participant stated:

> *The linking. I never gave it thought before. The relationships between levels in the hierarchy and between different concepts within the map. That would probably change my approach to a lot of things now.*

Interrelationships. Participants in this study also described a step beyond linking. They indicated that as a result of making links between concepts, they began to really understand and search out interrelationships between concepts that created new meaning for them. As one participant explained:

> *As I did the concept maps, I was particularly sensitive to find what the interconnections were. I did our case studies and I went through the readings; whatever we had to concept map, I was more aware of*

the connections, what are the relationships, because I knew eventually I had to produce that in the map.

Another participant described how after learning to make links, the process of developing interconnections helped him critique his own thinking by highlighting false connections he had made previously. As a result, he felt that finding the connections was a way of double-checking his understanding of new material.

After I did a couple of maps I realized that these were the things that I was trying to do mentally. Sometimes I would see the mistakes or let's say just mis-connections. Like no, this really doesn't connect to this. This really should connect over here. You could almost, like, check your math. It is like doing math the long way as opposed to taking some shortcuts. Every once in awhile you made a mistake and then you had to go back. It was kind of like long division.

Creating Meaning Schemes. A number of participants also indicated that subsequent to linking and searching out interconnections, the mapping exercise fostered the learning process or strategy of creating meaning schemes. Most participants described these schemes as a way to organize and structure information. Additionally, participants indicated that in the process of creating schemes of information their ability to recall the information was improved.

Well, doing the concept map forms the schemes for learning. It forced me where the author didn't put a framework, to put one. So I believe that although it takes longer to read and do a concept map in order to retain what you are doing or to develop an idea that way, that I definitely knew after doing a couple that the retention was going to be greater because the scheme was etched in your mind then.

Knowledge Construction. Finally, participants indicated that through the process of developing a concept map, they learned that linking, developing interrelationships and creating mental schemes all helped them develop their ability to construct a knowledge base for themselves. One participant expressed the way she began to understand the process of creating a concept map as similar to creating a mosaic. She stated:

I think that helped with the whole process because with a mosaic you have a bunch of little pieces and you are kind of figuring out what is the best way to array them, how many little pieces you have, and what comes after what. That concept plus the learning fell in with my understanding or belief of how adults learn. I guess it would be kind of a constructivist approach as we build on what we already know, we add too, we might reshape what we already have in our brains, based on what new stuff comes in. It may be reshaped or you may just add to your database. I felt like the concept mapping process really helped with that.

Another participant describes a similar connection between developing concept maps and constructing knowledge. She stated:

I really believe in concept mapping because I believe in constructing knowledge. Dialog, discovery, constructing knowledge, all that stuff. It really does fit in. Maybe that is why I do like it because it does give you a chance to kind of sort stuff out and construct knowledge.

5.2.3 Changes in Thinking

At the conclusion of the first semester of this study, participants were asked if their thinking changed as a result of the use of concept maps and, if so, how. Participants described how this strategy was different than other learning strategies and that their thinking did change. Participants expressed how they analyzed concepts in more depth and they felt they had the ability to make connections across multiple bodies of knowledge. For example, one participant stated:

It is different because any other strategy, taking notes, putting together a formal outline, one thing after another. Whereas, the concept map gets you to think outside of the box. It gets you to see how things relate rather than how one thing is broken down. So it was a different way of approaching something, taking a different perspective on learning, I thought, which was refreshing for me.

Finally, one participant indicated that the mapping process helped her to think better and also helped her to recognize that she really developed an understanding of what she learned.

I don't know if this makes sense, but concept mapping allowed me to think better. It really allows you to understand what you are reading and as you are doing it, you are putting it together, and all of a sudden when you are done and you think to yourself when you look at sort of the arrows that are going back and forth and the connections that you have made, and you sort of look at yourself and you think, wow, I guess I really get that. I get it thoroughly as opposed to something you just read and five minutes later you asked me what I just read and I am not able to answer the first question.

5.3 Follow-Up After One Year

One of the major research questions this study addressed was do adult graduate students continue to use concept mapping as a learning strategy even when they are in courses that do not require them to do so. In this study, 65% of adult learners reported that they did continue to use this strategy. Those participants who reported that they continued to use mapping explained that they did so for a number of reasons. They seemed to use maps to understand course material in subsequent graduate courses. They also relied on the maps as a way to understand particularly difficulty material. Many participants reported that when they felt "in trouble" in a course or that they "did not get it," they would try mapping out the material as a way to develop their understanding. Additionally, learners tended to use maps to frame projects for subsequent courses or work-related projects. One participant described how he had a big project to do at work and as a way to help his team understand the scope of the project, he mapped it out and shared the map with them. Another student described how she used a concept map in a subsequent class to demonstrate decision making.

The adult students who did not use concept maps in the subsequent semester (35%), reported that they chose not to because they were not required, they did not have time or they did not have the software they needed to develop the maps. However, the biggest barrier to creating maps for this group was time. Over and over again, these learners complained that the process took more time than they felt they could invest in their course work.

Interestingly, in this study both learners who used concept maps in subsequent semesters and those who did not still reported changes in their thinking at one-year follow up. For example, students who used the mapping tended to report that the maps increased their focus, understanding of relationships, and thinking processes. The following quote is from a learner who did use the maps in the follow up semester:

I am more conscious, especially in the class I just had, I was conscious of how do these different concepts interrelate. What are the connections that I am making in my mind? That is why I went to the concept map. Because my mind was doing stuff, but I wanted to get it down on paper so I could look at it.

On the other hand, the learners who chose not to use concept maps in subsequent semesters still reported changes in their thinking. These learners reported being able to identify interconnections, organize information and develop mental schemes for their reading. The following quote is from a learner who had not used mapping in the subsequent semester:

Although I haven't used them, I think in the way I organize my textbook and in how I write some of my notes, that it is actually a variance of a map. I never used those little stickies before. I highlight them in different colors now. What I will try to do is try to group them according to color, so that when go back I can tell that this one kind of goes with this one which is yellow. This one is hot pink and I have found that it helps to organize in that way.

6 Discussion

Results of this study indicate that adult graduate students learned to develop concept maps and, through the process of using this constructivist learning strategy they developed their thinking abilities and grew to understand their own learning processes. Interestingly, 65% of students continued to use this strategy at one-year follow-up even when enrolled in courses where it was not required that they do so.

A number of issues surfaced in this study. First, it was surprising that many adult graduate students participating in this study began with so little understanding of their own learning processes. Second, it was evident how resistant some students were to changing their learning processes, even when they were unsure of the nature of those learning processes. It took a great deal of work for many students who participated in this study to find the willingness to try this learning strategy and to learn how to use concept maps. Finally, it was interesting to note that once study participants did understand their own learning, they continued to move forward in developing their thinking abilities even if they did not use the concept map explicitly.

Results of this study support previous work on concept mapping (Novak & Gowin, 1984; Novak, 1998), but also seem to indicate that there is long-term change in participants thinking abilities as a result of learning to develop maps. Additional longitudinal research is needed to substantiate this finding.

7 Implications for Adult and Higher Education

This study has implications for faculty in adult and higher education programs. Students in this study demonstrated that concept maps helped them to understand the learning processes of linking, developing interrelationships, creating meaning schemes and constructing knowledge bases. Once they were able to learn in this fashion and explain their own learning, they were much better prepared to function in future graduate courses and as educational professionals promoting learning and change. A number of students shared examples and cases where they used mapping in their organizations to analyze performance projects, develop strategic plans, teach leadership, support decision-making and brainstorm new ideas. The major implication here, for faculty in adult and higher education, is that adult student often do not understand their own learning processes and need practice with learning strategies that will help them develop their learning and thinking abilities. Once students develop more complex learning strategies, they are then better prepared to think critically and analytically about specific content they are learning.

The biggest challenge for faculty in adult and higher education programs is changing teaching approaches to incorporate what we know about adult student learning. Using concept maps necessitates that faculty have a good understanding of constructivist learning and the ways in which maps represent students' thinking. To use this strategy effectively faculty need to create their own concept maps that demonstrate subsumption, progressive differentiation and integrative reconciliation (Novak & Gowin, 1984). Finally, to use mapping faculty need to be willing to foster an approach to learning as meaning construction. This means that the focus of courses shifts from teaching and presenting information to learning and creating meaning. 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 indicates that concept maps can effectively promote learning of adult students and thus, can be added to the teaching strategies of faculty in higher education. The maps contribute to student success, foster a long-term change in thinking, and contribute to changing adult students' learning strategies. The maps support both constructivist teaching and learning approaches and may have wider applicability to the work world as well.

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USING CONCEPT MAPS IN QUALITATIVE RESEARCH

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Abstract. Despite the huge increase in the number of qualitative research studies conducted, using concept maps as a methodological research strategy has received little attention in recent literature. This paper will discuss the connections between qualitative research and concept maps. Additionally, four strategies for incorporating concept maps in qualitative research will be presented along with sample maps for each strategy. Finally, advantages and disadvantages of using concept maps in qualitative research will be discussed.

1 Introduction

Qualitative research as a form of inquiry has grown tremendously in the last decade. The number and quality of qualitative studies in almost every discipline has increased. In addition, sophisticated computerized software programs have been developed to assist with the data analysis process in qualitative inquiry.

The focus of qualitative research tends to be on understanding the meaning imbedded in participant experiences through an open-ended, unstructured and subjective approach (Lincoln & Guba, 1985). The research is most often conducted in a naturalistic setting with a purposive sample (Patton, 2002). The research tends to be holistic, descriptive and focuses on the depth and details of experiences (Denzin & Lincoln, 1998). Data collection methods include interviews, observations, field notes, and documents to name a few (Wolcott, 1994). Data tend to be analyzed through an inductive, ongoing and evolving process of identifying themes within a particular context (Miles & Huberman, 1994). As Creswell (1998) indicates,

> Qualitative research is an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyzes words, reports detailed views of informants and conducts the study in a natural setting (p15).

1.1 Challenges in Qualitative Research

Researchers engaged in qualitative inquiry find varying challenges in the process. Often these challenges have to do with the data analysis process. In qualitative inquiry, researchers need to take voluminous amounts of text-based data and reduce that data to a manageable form without loosing the embedded meaning. Additionally, qualitative researchers are challenged to make the process they use in data analysis transparent. Often qualitative studies describe the data analyses as a process of reading and re-reading transcripts until themes emerge. This type of description makes it difficult for subsequent researchers to understand not only the analysis process, but to understand where and how the findings have emerged from the data. If readers can not rely on the credibility and trustworthiness (Lincoln & Guba, 1985) of the analysis process, then the findings from qualitative studies tend to become suspect.

Concept maps can provide one strategy to deal with the methodologic challenges of qualitative research. A concept map (Novak, 1998) can be used to frame a research project, reduce qualitative data, analyze themes and interconnections in a study, and present findings. "A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions" (Novak and Gowin, 1984, p. 15). Concept maps are created with the broader, more inclusive concepts at the top of the hierarchy, connecting through linking words with other concepts than can be subsumed. Concept maps are an important strategy in qualitative inquiry because they help the researcher focus on meaning. The maps allow the researcher to see participants' meaning, as well as, the connections that participants discuss across concepts or bodies of knowledge. Additionally, the maps support researchers in their attempts to make sure that qualitative data is embedded in a particular context. Since the maps focus on subsumption, progressive differentiation, and integrative reconciliation of concepts (Novak & Gowin, 1984) the research context remain an integral part of the data analysis process. The remainder of this paper will focus on examples of how concept maps can be used in qualitative studies.

2 Mapping and Methods

2.1 Framing Research Projects

Concept maps can be used to frame or plan research projects. For example, the first map shown in Figure 1 was used to plan a research study investigating how the use of concept maps impacted the learning of adult students in higher education over two semesters.

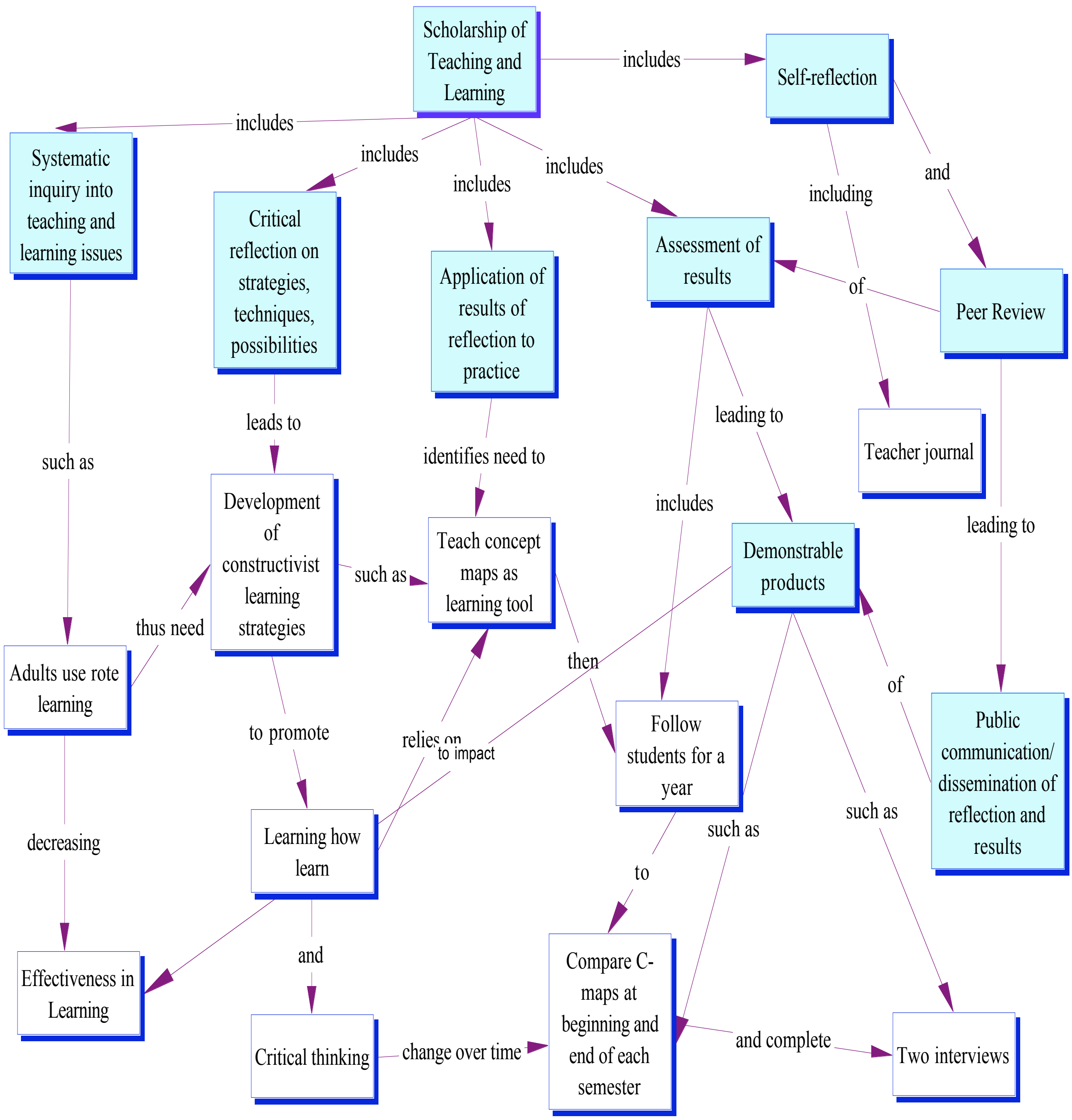

Figure 1: Applying the Scholarship of Teaching and Learning: Understanding Adult Students in Higher Education

Part of the purpose of this research was to link the study to the eight principles of the scholarship of teaching and learning (SOTL). (http://www.carnegiefoundation.org/CASTL/highered/index.htm). So in planning the study, these eight principles were presented (note blue concepts) on the concept map and the actual research project was linked to each of the eight principles (Daley, 2002). This map clearly depicted for other researchers how the SOTL principles were incorporated through out the research project. In planning research projects the maps serve the purpose of helping researchers to link the conceptual framework of the research to the actual research methods.

2.2 *Reducing Data*

One of the strengths of using concept maps in qualitative research is that it allows the researcher to reduce the data in a meaningful way. By using maps it is possible to display an average 20 page interview transcript on a single page. Using concept maps in the data reduction process, allows for the visual identification of themes and patterns. It also allows the researcher to capture meaning of the participant interviews because the maps display concepts in both a horizontal and vertical fashion. It is these linkages that facilitate the process of understanding interconnections and meanings in the data. The vertical linkages display how the participant differentiated concepts and the horizontal linkages display how the participant connected and related different areas of the study.

In addition, reducing qualitative data to a one page concept map can facilitate the process of cross-site or cross-group analysis. Sorting the one page maps by groups or sites can facilitate the process of comparing for similarities or highlighting differences. For example, in a study of how different professionals learn in their practice, concept maps were created of each interview. This allowed researchers to compare how nurses, adult educators, social workers, and lawyers learned (Daley, 2001).

2.3 *Analyzing Themes*

Concept maps also can be used as a strategy to search out and analyze themes in qualitative research. To identify these overarching themes requires that researcher identify interconnections between concepts. If the researcher is searching for specific interconnections, a concept map can be created from the interview transcript that demonstrates these connections. For example, in one study on how professionals learn the researcher was looking for the connections participants made between what they learned in formal continuing education programs and their professional practice. So concept maps were created of each interview the depicted what participants said about their knowledge from continuing education, the context in which they worked and their professional practice.

Figure 2 depicts the connections one participant, a social worker, in this study made. The map displayed here is difficult to read because of the complexity, and yet the interconnections are clear. At the top of this map are the concepts of knowledge, context and professional practice (in blue). The interconnections that the interview participant discussed are displayed in pink. The social worker in this interview had been to a continuing education program on long-term care issues. From the map, one can see that when returning to work she did share the content of the workshop with her supervisor. Additionally, she clarified how she could use this information in counseling clients.

Concept maps can also be used to help create a category or coding system in qualitative research. After the maps are created from each interview or observation, the researcher can go through these maps looking for levels of hierarchy, interconnections and repeated concepts. These items then may indicate emerging themes. The category system created can then be used in conjunction with computerized qualitative data analysis packages. Once the category system is created the actual data can be coded and concept maps can even be linked or tagged to individual data samples. Again this linking and tagging helps to keep the participant meaning and research context central in the data analysis process.

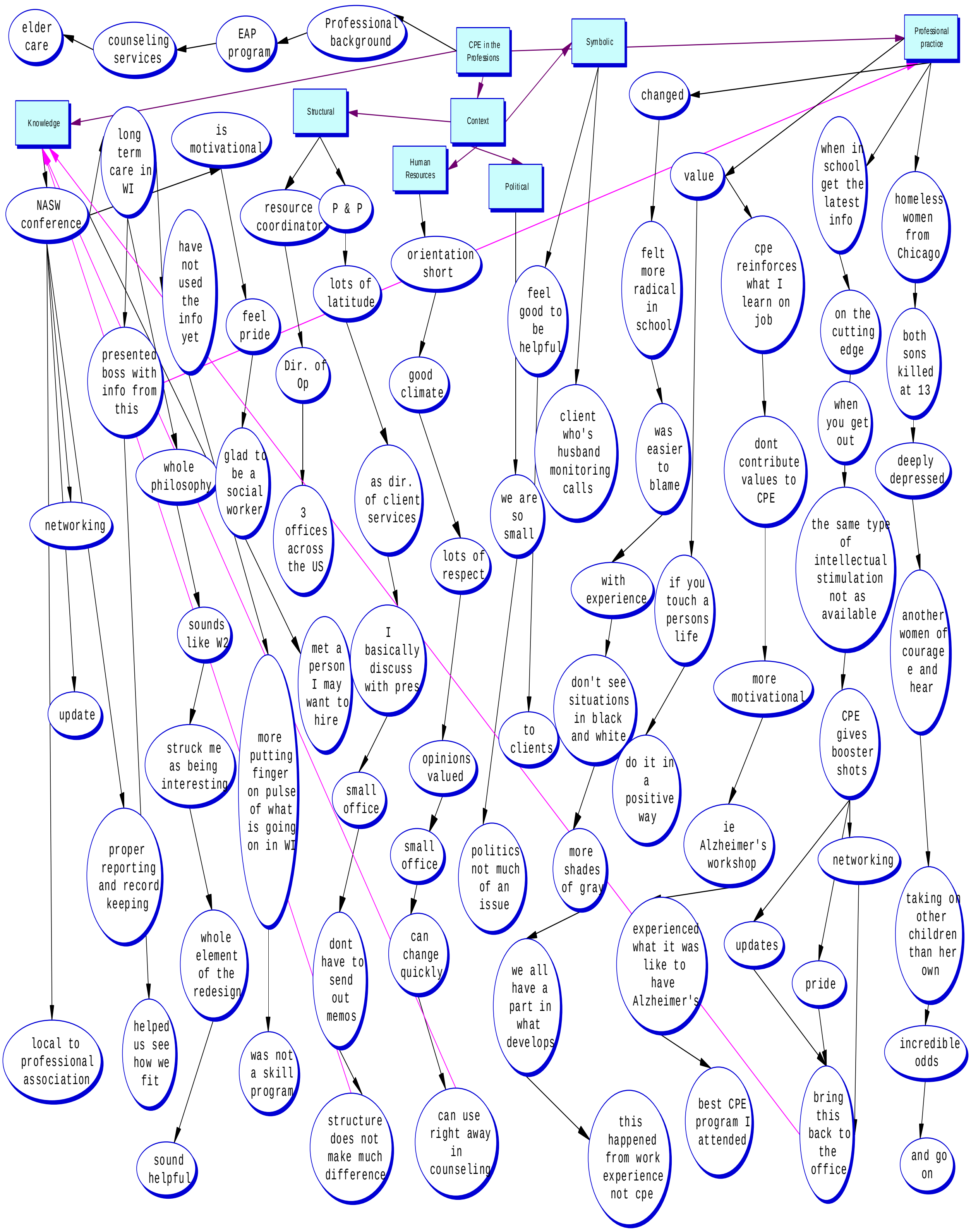

Figure 2: Concept Map of Social Worker Interview Depicting Connections between Knowledge, Context and Practice

2.4 Presenting Findings

Finally, concept maps can be used to present the findings of a qualitative research study. As a graphical display the maps can help readers understand the findings by providing a vehicle whereby the actual data quotes can be connected to larger parts of the study. For example, in a study analyzing the different learning processes of novices and experts, researchers found that novice learning was often contingent on the novices need for validation, insecurity and fear of mistakes. Novices were still forming concepts in their practice and then when confronted by these feelings, they often described how they just wanted to be told what to learn. The map displayed in Figure 3 succinctly displays these findings.

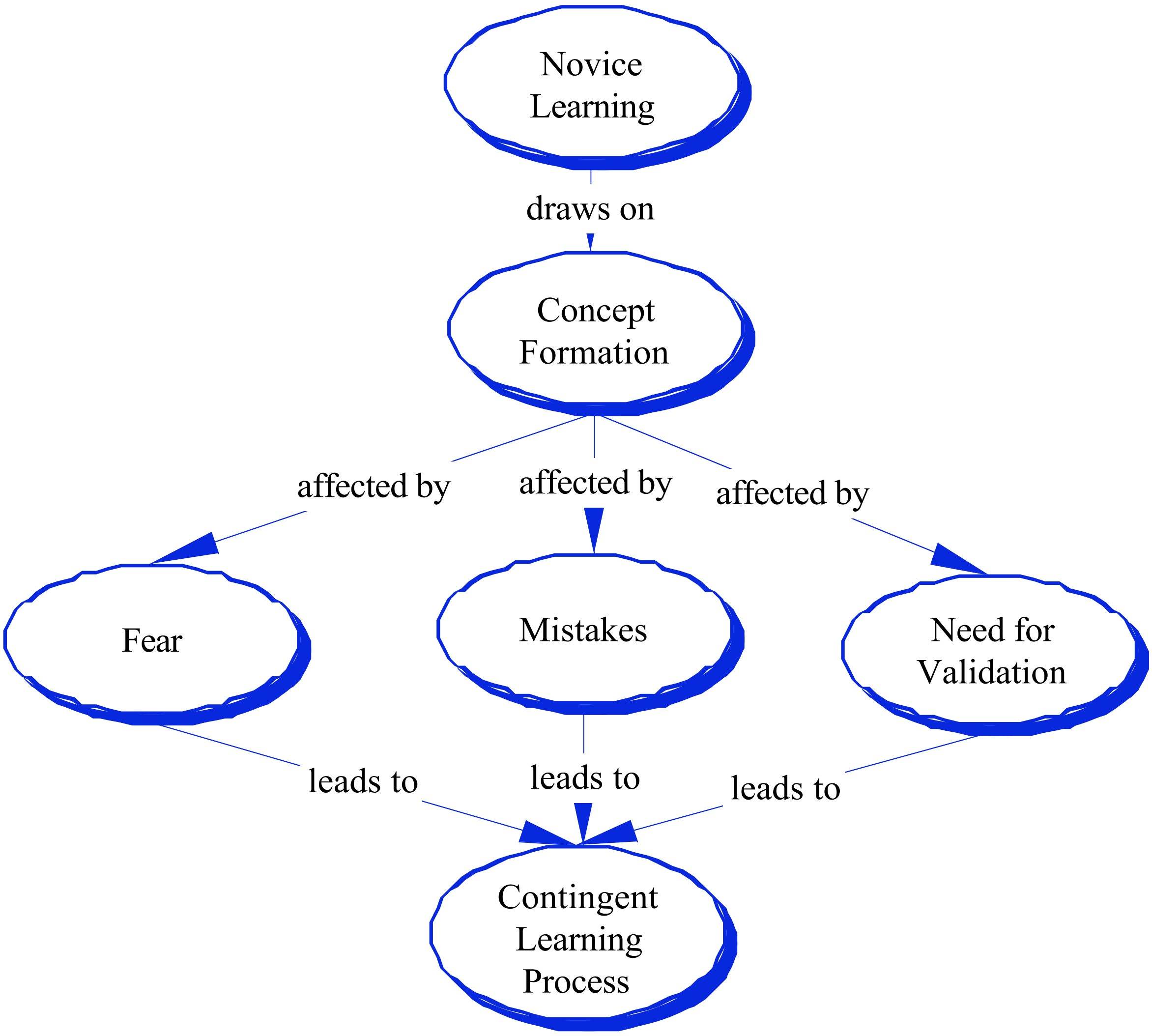

Figure 3: Learning Process of Novices
(Daley, 1999)

In contrast expert learning was found to be a more constructivist process based on an understanding of client need and the practice setting. In Figure 4 it is clear that experts integrate newly learned concepts with their experience through a process of dialogue and sharing (Daley, 1999).

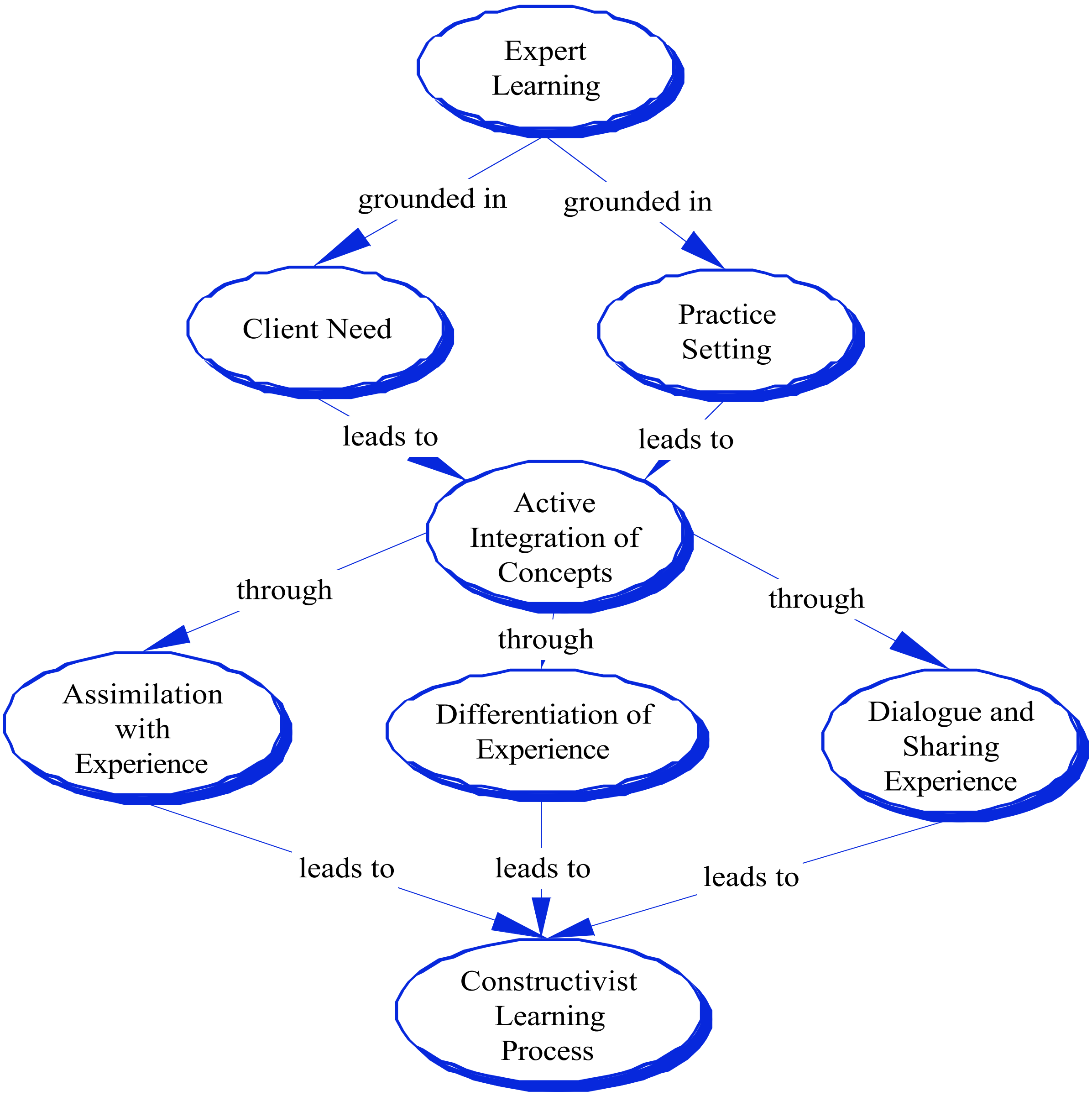

Figure 4: Learning Process of Experts
(Daley, 1999)

By using the maps in Figures 3 and 4, researchers were able to help the reader compare and contrast the findings of this study. The maps allowed for discussion of two clearly different learning processes and graphically displayed the differences for the reader.

3 Advantages and Disadvantages of Using Concept Maps in Qualitative Research

Using concept maps in qualitative research has a number of advantages. First, the maps help researchers to maintain the meaning of the interview within the data analysis. Often when looking at an interview transcript, the richness of the participants meaning can be lost. Because of the interconnections displayed on a concept map this meaning can be maintained. Transcripts tend to represent the spoken language in a linear fashion, where as the maps represent the interview data in an interconnected and hierarchical fashion. This representation is more analogous to the way we think and to the way we actually discuss concepts in an interview format. Concept maps created from interview transcripts allows the researcher to probe the human cognitive structures and then to represent these structures by linking concepts within a framework of propositions. Second, the maps are advantageous in that they support the philosophical underpinnings of qualitative research and they help operationalize this philosophy in the data analysis process. Third, concept maps also help reduce the volume of the data, display linkages, and facilitate cross group or site comparisons. Additionally, the maps can be returned to participants and participants can be asked to review the map and make sure the researcher is accurately understanding and conveying the meaning of what the participant discussed in the interview. Finally, concept maps are a qualitative data analysis strategy that can be used with other strategies in the same study. For example, the maps can be used to support the creation of coding and categorization systems, as well as the development of matrices.

The major disadvantage of using concept maps in qualitative work seems to be their complexity. The maps can be difficult for participants unfamiliar with the format to read and the linkages may be harder to see as the maps get more and more complex as demonstrated in Figure 2. Because of this complexity, it is most often necessary to use other data analysis strategies in conjunction with the maps. Additionally, the complexity at times makes it difficult for the reader to determine what concepts are of critical importance and what concepts are of secondary importance.

4 Summary

Miles and Huberman (1994) indicate that the data analysis process in qualitative research contains the three sub-processes of data reduction, data display, and conclusion drawing. In this paper it is demonstrated how concept maps can be involved in each of these sub-process, as well as, in thematic analysis and the framing of research projects. One of the biggest advantages of using concept maps in qualitative research is that they can be applied in multiple studies and with multiple kinds of data. Despite the disadvantage of complexity, concept maps can serve as an important advance in qualitative research and data analysis.

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LOS MAPAS CONCEPTUALES COMO HERRAMIENTA DE APRENDIZAJE ORGANIZACIONAL: APROXIMACIÓN A UN MARCO TEÓRICO Y PRESENTACIÓN DE RESULTADOS PARCIALES DE UN PROYECTO.

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Abstract. La Teoría del Aprendizaje Significativo y sus herramientas asociadas, como los mapas conceptuales, pueden aportar contribuciones importantes al funcionamiento de las organizaciones modernas. En este artículo se presentan los resultados preliminares de un proyecto de Aprendizaje Organizacional que emplea los mapas conceptuales y otros elementos de esta Teoría, así como algunas reflexiones teóricas acerca de la posible integración de la Teoría del Aprendizaje Significativo en las diversas teorías de aprendizaje organizacional.

1 Introducción

Durante los últimos años numerosos autores abundan en considerar al conocimiento como el recurso más importante que posee una organización para conseguir y mantener una ventaja competitiva (Drucker, 1993). Se entiende aquí conocimiento como un fenómeno creado y acumulado a través de un proceso denominado aprendizaje organizacional (Pawlowsky 2001). El aprendizaje organizacional ocurre cuando "los individuos de la organización experimentan una situación problemática y se preguntan por el comportamiento de la organización"; por otra parte, "el aprendizaje, para que pueda ser considerado organizacional, debe ser incorporado (...) mediante artefactos epistemológicos (mapas, memorias y programas) que se encuentren en el ambiente de la organización" (Argyris & Schön, 1996). Los objetivos de este artículo son tres. Primero, exponer un marco teórico en el que puedan analizarse y evaluarse las acciones de aprendizaje organizacional, y que a su vez pueda describir los mapas conceptuales como herramienta en proyectos de aprendizaje organizacional. Segundo, comparar brevemente los postulados de este marco teórico con los de la teoría del aprendizaje significativo (Ausubel Novak & Hanesian, 1978). Y, finalmente, presentar los resultados preliminares de un proyecto de aprendizaje organizacional que emplea elementos de esta teoría y los mapas conceptuales en algunas de sus fases.

2 Exposición del caso

Lafitt SA comenzó trabajando con sustituciones articulares de rodilla y cadera, y con placas de traumatología para fracturas de huesos largos, productos que por entonces ya tenían una larga vida en el mercado y eran bien conocidos por los fundadores de la empresa. En 1997 la dirección se planteó la entrada en el mercado de implantes para la columna vertebral, que constituye el sector el de mayor crecimiento potencial en el mercado de los implantes quirúrgicos. Estos implantes son considerados como de "gama alta", puesto que están destinados a una cirugía –la que trata las patologías de la columna vertebral- reciente, difícil y de gran complejidad.

Tras aumentar el tamaño del departamento de I+D -encargado del diseño y desarrollo del producto- con la incorporación de 2 ingenieros y de 2 delineantes, la empresa aumentó a su vez el tamaño de su departamento de ventas, con la contratación de 3 nuevos delegados comerciales para el territorio nacional, manteniendo los mismos recursos para el mercado internacional, cuyo director de ventas era el único que poseía experiencia previa en el mercado de implantes de columna. A mediados del año 2000 la empresa contaba ya con un producto listo para salir al mercado, un "fijador transpedicular", implante considerado como el "gold standard" de la cirugía de columna y que se consideraba necesario para el desarrollo futuro de una línea de productos para este tipo de intervenciones.

Dos años y medio más tarde, los resultados de venta de este producto en el territorio nacional estaban muy por debajo de lo esperado, mientras que los de internacional se ajustaban al crecimiento previsto. Tras analizar las posibles causas de este hecho (las características del diseño del producto, o la presión de la competencia en el territorio nacional, integrada principalmente por multinacionales norteamericanas) la dirección concluyó que el problema estribaba en la lentitud con la que el personal de ventas había adquirido el conocimiento necesario para enfrentarse al mercado. Es extremadamente importante (tanto que puede definirse como uno de los objetivos estratégicos principales de la empresa) que el delegado comercial sea capaz de mantener un diálogo con el médico en términos científicos, al menos en lo que se refiere al entorno de aplicación del implante. Gran parte del marketing del sector se dedica a proporcionar al fabricante cierta "legitimidad" científica, que debe ser confirmada por el representante de la empresa ante el cliente.

Por otra parte, al final de este periodo los tres delegados de ventas han sido contratados por otras empresas, siendo reemplazados por nuevos delegados sin experiencia en el sector. La empresa se enfrenta al siguiente problema: la formación de los delegados de ventas es esencial en un mercado tan exigente, pero esta formación es tan larga que limita notablemente el potencial del departamento. Además, la movilidad laboral de este colectivo es muy alta: un delegado de ventas con cierta experiencia resulta muy atractivo para las empresas de la competencia, que poseen más recursos ya que pertenecen a grandes corporaciones.

Lafitt SA ha colaborado a lo largo su trayectoria con numerosos centros tecnológicos, como el IBV (Instituto de Biomecánica de Valencia) o AIMME (Asociación de la Industria Metalmecánica). En este caso, y debido en parte a la colaboración de uno de sus empleados con la institución, se buscó el asesoramiento de INGENIO (Instituto para la Gestión de la Innovación y el Conocimiento). Los componentes del Grupo de Gestión de Conocimiento de INGENIO utilizan de manera habitual la herramienta de los mapas conceptuales como un método para organizar y representar el conocimiento (González, Ibáñez, Casalí, Rodríguez & Novak, 2000), debido, entre otras razones, a su convencimiento de que la teoría del aprendizaje significativo posee un gran potencial de aplicación en el ámbito empresarial. Una vez conocida la situación, se concibió un proyecto de aprendizaje organizacional (inscrito en un modelo teórico que se define en el siguiente apartado) que fuera capaz de:

1. Identificar las carencias de conocimiento que causaron el problema; Identificar y localizar el conocimiento capaz de suplir estas carencias.
2. Generar dicho conocimiento
3. Diseminarlo a nivel intraorganizacional
4. Integrarlo en los "sistemas de conocimiento" de la organización
5. Transformar dicho conocimiento en conductas organizacionales.

En este artículo se presentan los resultados de las dos primeras fases del proyecto. La segunda de estas fases se ha basado en el empleo de mapas conceptuales, y está previsto que se emplee en dos de las tres siguientes. También se consideró la utilización de la herramienta como método para desarrollar actitudes positivas hacia el aprendizaje o hacia otras características psicológicas, como la creatividad y la comunicación intergrupal (Gonzalez & Cañas, 2002).

3 Marco conceptual

Pawlowsky (Pawlowsky, 2001) ha desarrollado un marco conceptual de aprendizaje organizacional basado en los elementos comunes de las diferentes perspectivas que han abordado este proceso desde que apareció por primera vez en la literatura (Cyert y March, 1963). Este modelo consiste en identificar las dimensiones fundamentales del proceso, para poder así analizar las acciones concretas que se emprenden y comprender mejor sus orígenes, su desarrollo y sus efectos (Figura 1).

La primera de estas dimensiones es el nivel del sistema en el que se produce el aprendizaje. Aunque aquí se alude a un problema ontológico y epistemológico de gran complejidad (qué clase de entidades son capaces de aprender[1]), parece obvio que, si se caracteriza de manera distinta el aprendizaje de la organización del aprendizaje de los individuos, el marco conceptual debe ser capaz de distinguir, al menos descriptivamente, entre diferentes sujetos del aprendizaje. Pawlowky define como "niveles" de aprendizaje al individuo dentro de la organización, al grupo, a la organización misma como entidad que aprende, y al aprendizaje interorganizacional como interacción entre este último tipo de entidades.

La segunda dimensión es la orientación del aprendizaje que se lleva a cabo: cognitivo, cultural o conativo (o aprendizaje mediante la acción). Si bien la Teoría del Aprendizaje Significativo (Ausubel Novak & Hanesian, 1978) propone precisamente un modelo de aprendizaje que integra estas tres orientaciones, creemos que, de nuevo por razones esencialmente descriptivas, es útil caracterizar una herramienta o acción de aprendizaje organizacional mencionando su orientación dominante (y la cursiva recalca en este caso el carácter integral del aprendizaje).

[1] "Las organizaciones aprenden: asumir que las organizaciones manejan los mismos procesos de aprendizaje que los seres humanos parece excesivamente ingenuo, pero el hecho es que las organizaciones (como otras instituciones sociales) muestran un comportamiento adaptativo a lo largo del tiempo" (Cyert y March, 1961)

La tercera dimensión es el tipo de aprendizaje que se logra mediante la herramienta utilizada o la acción emprendida. Puesto que el aprendizaje organizacional nació como un intento por inscribir dentro de una teoría los esfuerzos realizados por las organizaciones por sobrevivir en entornos cada vez más competitivos, los tipos de aprendizaje descritos en el modelo de Pawlowsky tienen una fuerte impronta evolucionista. Así, los tipos descritos se refieren esencialmente al grado de complejidad y de autoconciencia del sujeto respecto a su relación con el ambiente y consigo mismo como aprendiz. Como aprendizaje de Tipo I o de "bucle simple" se concibe como una corrección de las desviaciones en el comportamiento de la organización realizada mediante operaciones "normales" dentro del funcionamiento de la organización. Aprendizaje de Tipo II o de "doble bucle" es el que implica una adaptación al entorno, y por tanto una toma de conciencia (y eventualmente una modificación) de los modelos asumidos por la organización en su relación con aquél. Por último, el "deutero-aprendizaje" o aprendizaje de Tipo III se refiere a un tipo de análisis profundo acerca de las estructuras "cognitivas" y conductuales de la organización. Es llamativa la gran diferencia que se advierte entre esta tipología del aprendizaje organizacional y la dualidad aprendizaje significativo-aprendizaje memorístico de la teoría del Aprendizaje Significativo. Una explicación posible es que esta teoría nació dentro del ámbito de la pedagogía, en el que el aprendizaje tiene como objetivo la asimilación significativa por parte del alumno de ciertas disciplinas; la impronta evolucionista del aprendizaje organizacional, como hemos explicado, se debe a que busca un aprendizaje que dé con el conocimiento capaz evitar la desaparición de la organización. En este sentido, la construcción de los significados que forman una disciplina parece tener estrecha relación con el *interés* que guía dicha disciplina (Habermas, 1981).

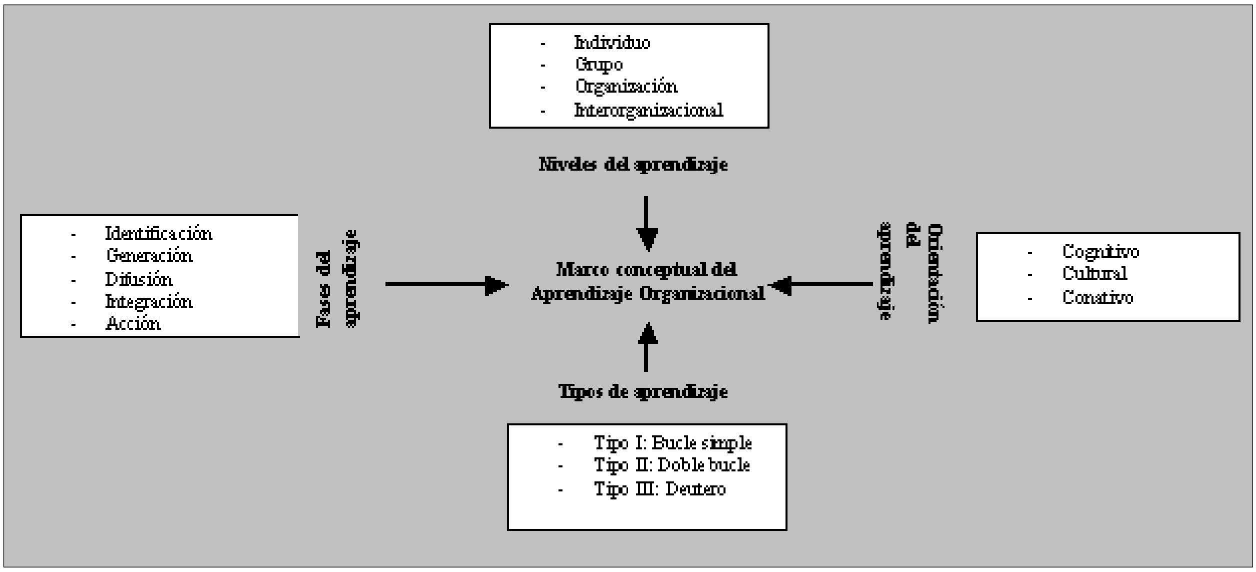

Figura 1. Marco Conceptual de Aprendizaje Organizacional. Adaptado de Pawlowsky, 2001

Finalmente, Pawlowsky distingue entre las diversas fases del proceso de aprendizaje organizacional, para poder así asignar a cada una de esas fases los recursos y herramientas adecuadas a sus objetivos. La fase de *identificación* consiste en localización de la información que puede ser relevante para el aprendizaje; la fase de *generación* se refiere a la creación de nuevo conocimiento; la tercera fase es la de *diseminación* del conocimiento a través de los diferentes niveles (individuo, grupo, organización) que participan en el proceso; la cuarta fase consiste en la *integración* del conocimiento generado y diseminado en las "estructuras cognitivas", llamadas usualmente "sistemas de conocimiento" de la organización (Pawlowsky, 2001). La quinta y última fase se refiere a la *transformación* del conocimiento en acción y a su efecto en la conducta organizacional estándar. Aunque la Teoría del Aprendizaje Significativo no los denomina estrictamente fases, es de destacar de nuevo la muy diferente perspectiva con la que aborda los procesos de asimilación de conocimiento, como inclusión, inclusión obliterativa, diferenciación progresiva, reconciliación integradora o aprendizaje supraordenado.

Mediante estas dimensiones es posible caracterizar una herramienta de aprendizaje organizacional (Pawlowsky, Forslin & Reinhardt, 2001). En el apartado 6, "Discusión y Conclusiones", propondremos una caracterización de este tipo de los mapas conceptuales empleados en el proyecto de aprendizaje organizacional llevado a cabo por Lafitt SA e INGENIO. A continuación describiremos las fases ya concluidas de dicho proyecto: identificación y generación de conocimiento.

4 Identificación del Conocimiento

4.1 Identificación de la carencia de conocimiento.

El conocimiento está construido por conceptos y proposiciones. Algunos de los significados construidos pueden ser erróneos e impedir la construcción de nuevos significados. Los errores surgen de las jerarquías proposicionales limitadas o inapropiadas (también llamadas LIPH, *Limited or Inapropiate Propositional Hierarchies*): como el significado de todo concepto está construido mediante la serie de proposiciones en las que está inserto, un aprendizaje que parte de jerarquías LIPH conducirá a la incorporación errónea de nuevos significados o paralizará la incorporación efectiva de estos (Gonzalez, Morón & Novak, 2001).

Partiendo de estos postulados, se concluyó que la deficiente y lenta capacitación de los delegados comerciales era debida a la deficiente jerarquía proposicional con la que eran instruidos. Además de la experiencia directa en quirófano, normalmente la formación del personal de ventas se limita a la lectura individual de una serie de manuales de nivel básico para médicos o enfermeros por un lado, y de una descripción biomecánica del producto proporcionada por el departamento de I+D, por otro. Es decir, no se orienta el aprendizaje hacia los individuos que se desea formar (los vendedores, pertenecientes a un contexto específico, el empresarial, y que poseen una formación previa muy heterogénea) sino que se utilizan materiales destinados a otras comunidades y a otros objetivos formativos o tecnológicos. Como consecuencia, el aprendiz se ve abrumado por conceptos de anatomía patológica o biomecánica, que le cuesta estructurar y relacionar con el producto que vende.

4.2 Identificación de expertos

El paso siguiente lo constituyó la identificación de los expertos cuyo conocimiento pudiera resolver las carencias detectadas. La identificación de expertos se realizó mediante métodos cualitativos, dado el pequeño tamaño de la empresa; se utilizó el método de nominación, basado en la existencia y aceptación de una opinión cualificada (Loveridge, 2002). En este caso, se eligió al Director Técnico -responsable ante la Dirección General de los departamentos de I+D y Fabricación- como poseedor de opinión cualificada, dado que ha desempeñado esta labor desde la fundación de la empresa, estando además durante cuatro años a cargo del departamento de I+D de otra empresa multinacional del mismo sector. Se eligió como experto al Ingeniero de I+D encargado del desarrollo de productos para la columna vertebral. Las disciplinas que este experto maneja son diversas, pero todas están orientadas al producto, puesto que su labor es el desarrollo del mismo. Por tanto, se conjeturó que la jerarquía proposicional que podía proporcionar la representación del conocimiento del experto era el recurso que satisfaría la carencia detectada en el departamento de ventas, si se conseguía llevar a cabo correctamente la fase de generación del conocimiento.

5 Generación del Conocimiento

Los miembros de INGENIO adiestraron al experto en la elaboración de los mapas conceptuales. Los mapas conceptuales pueden ser considerados como una representación visual de la jerarquía y las relaciones entre conceptos contenidas por un individuo en su mente. Los mapas conceptuales están formados por "conceptos" y palabras denominadas "de enlace", que unen aquellos para constituir frases que tienen significado y se denominan "proposiciones". Los conceptos son regularidades percibidas en objetos o acontecimientos, designados por una etiqueta (Novak, 1998). Se eligió elaborar tres mapas conceptuales, acerca de los próximos productos a cargo del experto que iba a ser lanzados al mercado, y se explicó al experto que lo que se pretendía era reorientar la formación de los delegados comerciales, y que debería tener en cuenta este objetivo al elaborar los mapas. Los miembros de INGENIO asesoraron la realización de los mapas y revisaron sus diferentes versiones. El primer mapa que se realizó fue el de Placas Cervicales: en este mapa se decidió partir de un concepto que incluyera una gama de implantes más que un implante concreto, puesto que la empresa va a lanzar al menos dos productos de características diferentes dentro de está gama. Por lo tanto, el mapa se dedica a describir los atributos generales de las placas cervicales, así como las de las clases más habituales de esta gama de implantes. El siguiente mapa fue el de la Placa Lumbar Tic-Tac: este producto es el que supone una mayor innovación, puesto que se basa en un nuevo modo quirúrgico de abordar ciertas patologías. Por ello, en la cima conceptual se ha etiquetado el "proyecto placa tic-tac" en vez del producto concreto, para poder así desarrollar con mayor profundidad aspectos biomecánicos que, por su novedad, serán fundamentales para la aceptación inicial del producto, que precisará de una campaña de marketing distinta a la de los productos anteriores (cuyos principios ya han sido asimilados por el mercado), más orientada hacia conceptos quirúrgicos y biomecánicos. Por último se confeccionó el mapa de las Cajas Intersomáticas Porobloc: este mapa se dedica a un producto concreto, cuya característica específica es la utilización de un nuevo material. Por lo tanto, el mapa ilustra las características generales del producto, las del nuevo material, y las aportaciones funcionales que este nuevo material proporciona al producto, respecto a los materiales normalmente empleados.

En los mapas se repiten conceptos y proposiciones acerca de la fusión (o artrodesis) de las vértebras, función a la que están destinados los implantes para la columna vertebral, que deben anclarse como conceptos inclusores (Novak, 1998) en la jerarquía proposicional del aprendiz. Por otra parte, aunque en las Figuras 2, 3 y 4 los conceptos de los mapas no incluyen enlaces a otros recursos, en los mapas desarrollados hay una gran cantidad de imágenes subordinadas a los conceptos, fundamentales para ilustrar los conceptos relacionados con la anatomía descriptiva.

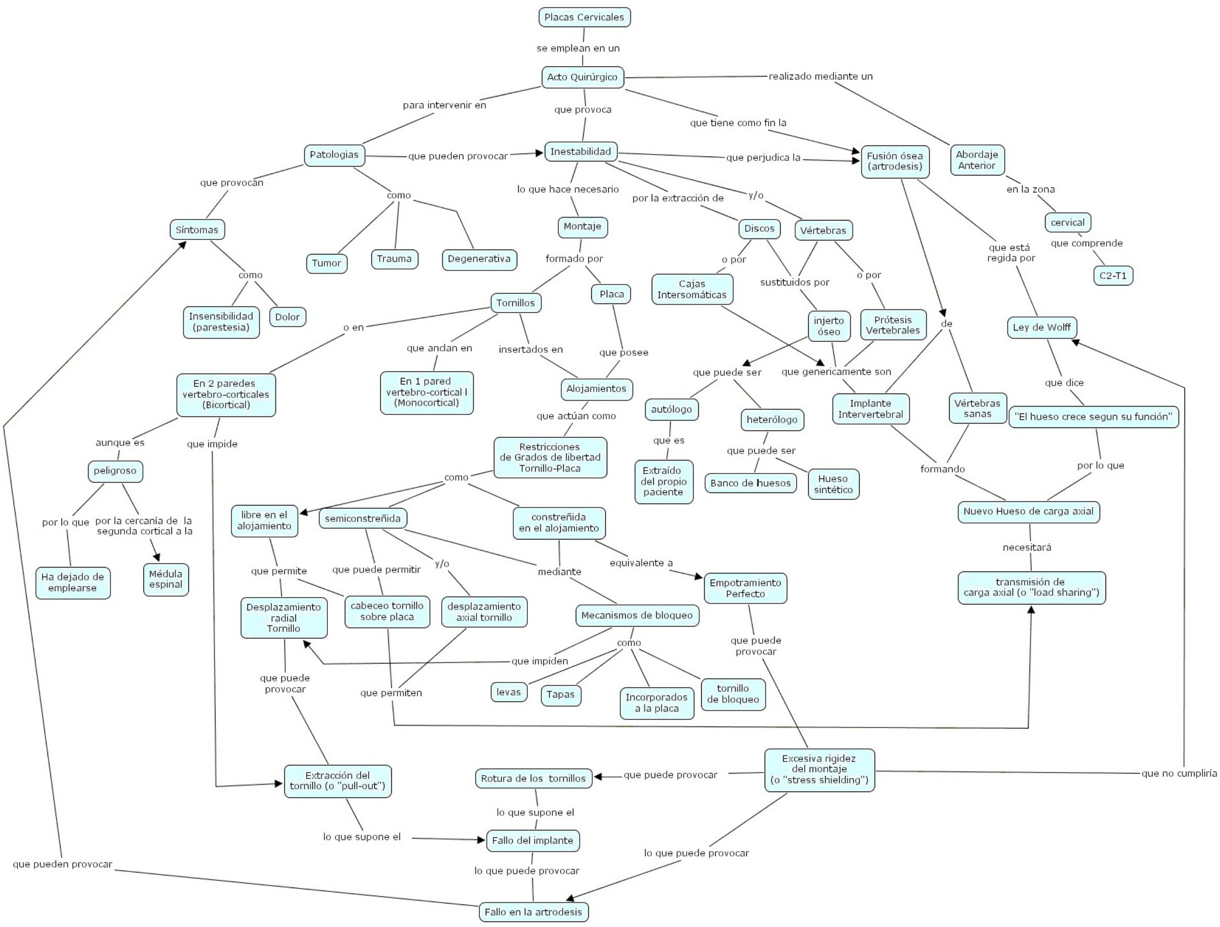

Figura 2. Mapa Conceptual: Placas Cervicales

6 Discusión y conclusiones

Las fases que restan en el proyecto son las siguientes: la *diseminación*, que consistirá en la elaboración de un programa de instrucción para el departamento comercial de los tres productos de los que se han realizado los mapas conceptuales. Esta instrucción utilizará como documentos organizadores estos mapas, y puede incluir su revisión. A continuación, la *integración*, que incluirá las dos fases anteriores, generación y diseminación de conocimiento, dentro del procedimiento habitual de formación del departamento comercial antes del lanzamiento de un nuevo producto. Y, por último, la *transformación* del conocimiento en acción, que podrá evaluarse y medirse mediante la revisión de los mapas según la experiencia comercial de los aprendices con el nuevo producto, añadiendo nuevos conceptos o modificando las jerarquías existentes. Una vez incorporada la utilización de los mapas conceptuales al funcionamiento habitual de la organización, puede contemplarse elaborarse nuevos mapas más centrados en estrategias de marketing que apoyen la transformación del cocimiento en acción.

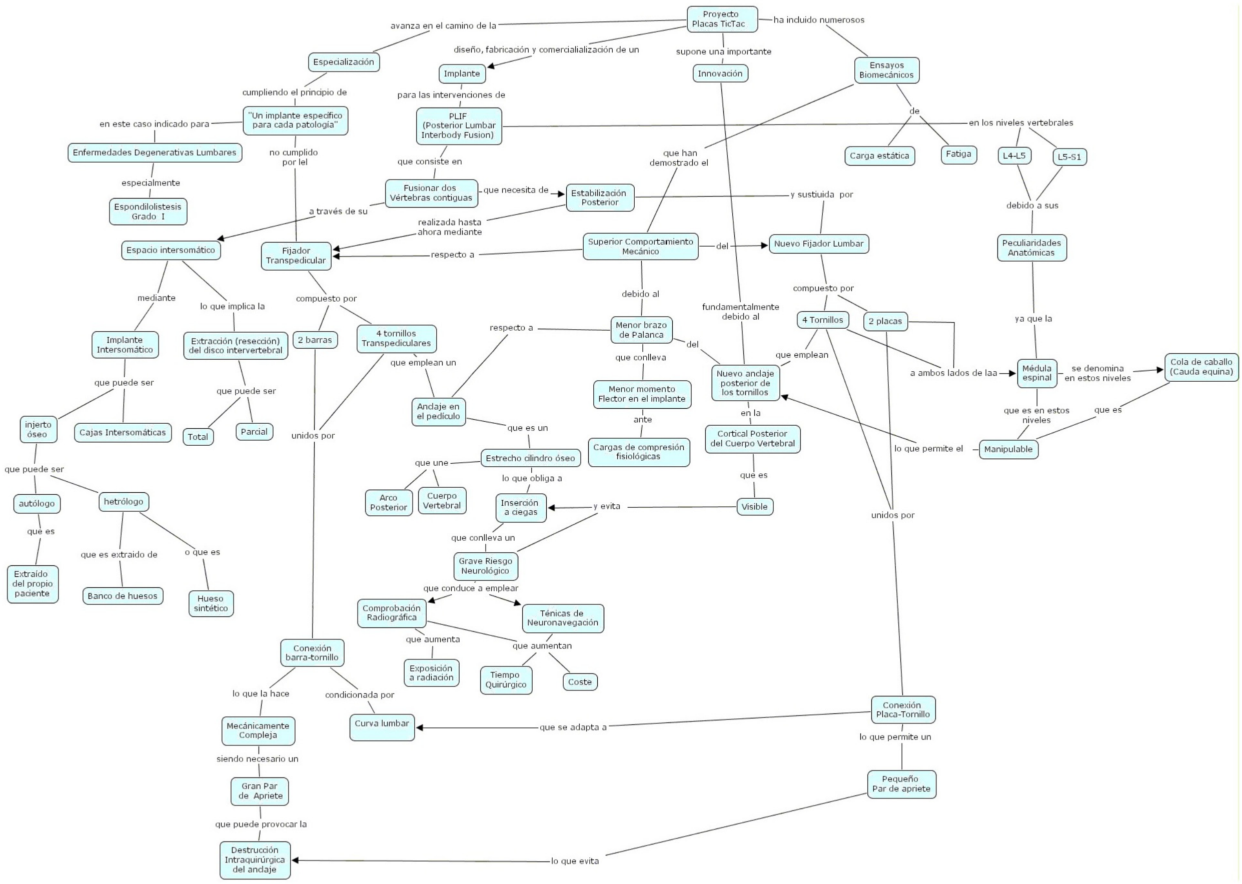

Figura 3. Mapa Conceptual: Placas Tic-Tac

En este proyecto se emplean mapas conceptuales en tres de las cinco fases del marco teórico en el que se inscribe el proyecto: generación, diseminación y transformación. La utilización de los mapas también puede ser descrita según el resto de dimensiones que forman dicho marco. Respecto al nivel de aprendizaje, los mapas pueden ser considerados una herramienta de aprendizaje individual o grupal, puesto que inciden en las jerarquías proposicionales de los miembros de un departamento, que serán instruidos como grupo. El tipo de aprendizaje será de Tipo II o de doble bucle, puesto que supone una adaptación de la organización a las características específicas del sector de implantes de columna vertebral, más complejo que el resto de sectores del mercado de implantes para cirugía ortopédica y traumatología; además, la organización se compromete a modificar su funcionamiento habitual para enfrentarse a esta adaptación. Por último, la orientación del aprendizaje es dominantemente cognitiva, pero también hay que tener en cuenta el aprendizaje cultural que supone la utilización de una herramienta como los mapas conceptuales. La Tabla 1expone sumariamente esta descripción de los mapas dentro del marco teórico del aprendizaje organizacional.

Herramienta	Nivel del aprendizaje	Tipo de Aprendizaje	Orientación del aprendizaje	Fase del aprendizaje
Mapas Conceptuales	Individual/ Grupo	Tipo II o doble bucle	Cognitivo/cultural	Generación/diseminación/trans formación

Tabla 1. Los Mapas Conceptuales como herramienta de aprendizaje organizacional.

En resumen, los mapas conceptuales pueden ser una herramienta muy poderosa en el aprendizaje organizacional. Pero la misma experiencia de la necesidad de una teoría de la educación que fundamente la práctica educativa para evitar la confusión metodológica y el aprendizaje disfuncional (Novak, 1998), ilustra el peligro de utilizar herramientas sin un armazón teórico sólido que soporte el peso de sus intenciones correctivas. ¿Puede ser la Teoría del Aprendizaje Significativo este armazón teórico en el ámbito empresarial?

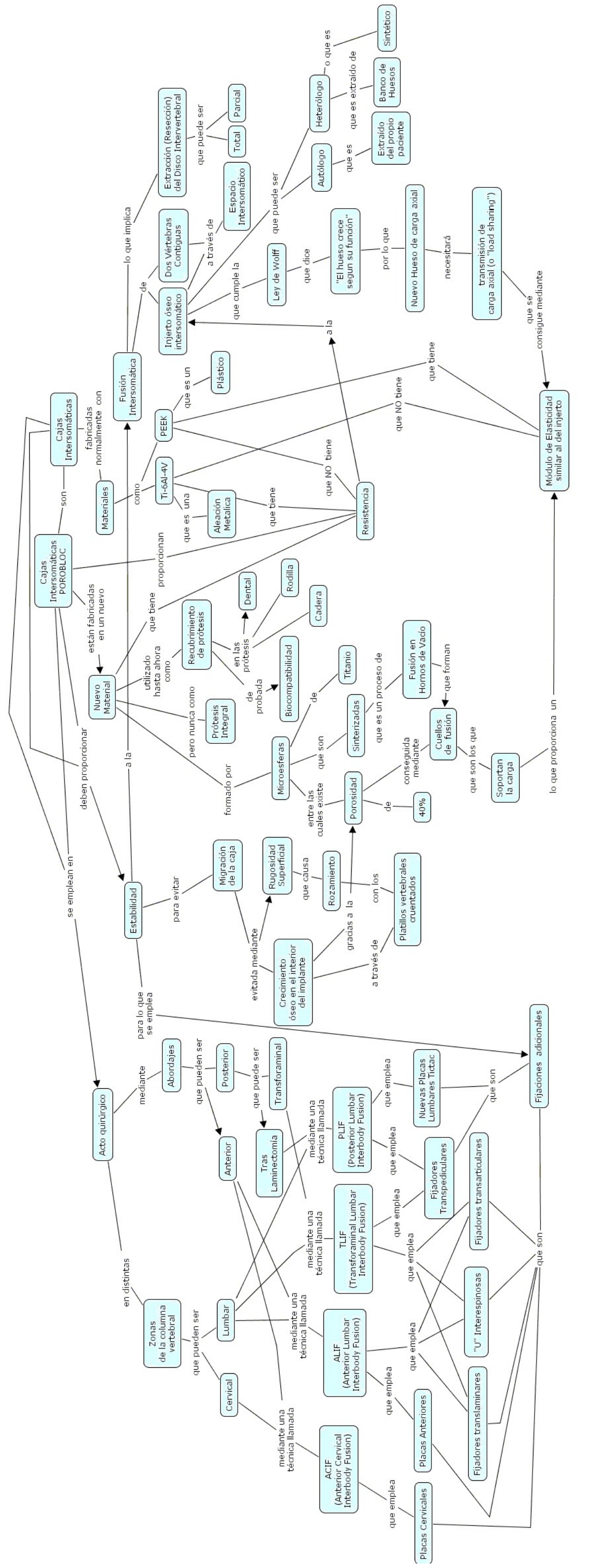

Figura 4. Mapa Conceptual: Cajas Intersomáticas Porobloc

Si las herramientas funcionan, como parecen hacerlo los mapas conceptuales, es de suponer que la teoría debería ser válida en cierto grado. De hecho, a lo largo de la exposición de los resultados de las dos primeras fases del proyecto (Identificación y Generación del conocimiento) hemos utilizado profusamente conceptos extraídos directamente de la Teoría del Aprendizaje Significativo. Sin embargo, como hemos visto en el apartado 3, existen ocasiones en que esta teoría parece no adaptarse al marco conceptual resultado de las reflexiones que hasta ahora se encuentran en la literatura de aprendizaje organizacional. Y también en este

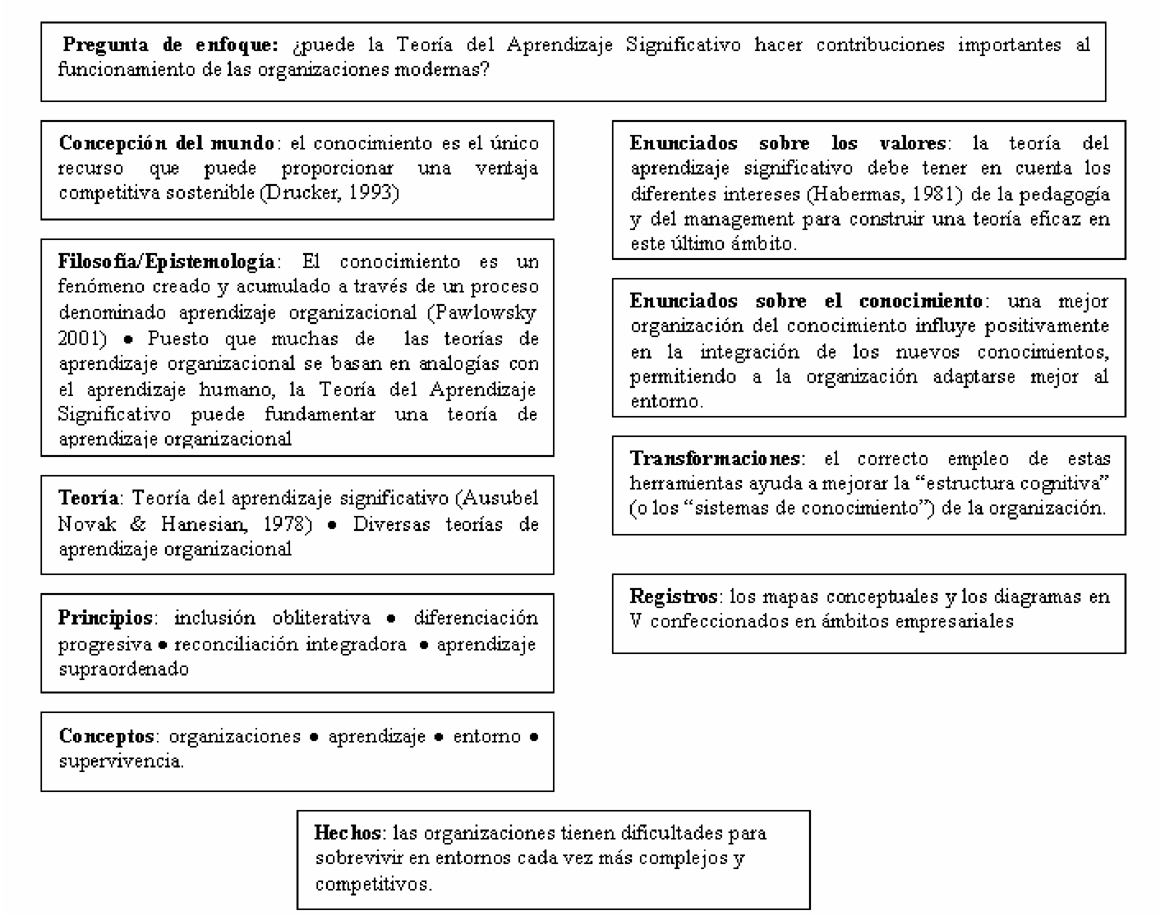

Figura 5 Diagrama en V construido en forma tabular

apartado hemos sugerido que la procedencia de ambas construcciones teóricas (una de la pedagogía y otra del management) bien puede haber influido en estas divergencias; pareciera como si el interés original que elige los significados que construirán una teoría debiera identificarse de algún modo con los intereses de su objeto de estudio. Como conclusión final de este artículo, incluimos un mapa en V (Figura 5) que pudiera guiar una futura investigación -teórica y empírica- integradora del aprendizaje significativo y organizacional.

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EXPERIMENTS ON THE EFFECTS OF MAP STRUCTURE AND CONCEPT QUANTIFICATION DURING CONCEPT MAP CONSTRUCTION

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Abstract. Two experiments were conducted. The first experiment compared cyclic and hierarchical concept maps, and measured the impact of concept quantification on the construction of both types of maps. The second experiment examined the preference for the two concept map structures. The results showed that structure does have a significant effect on the extent to which propositions imply a dynamic relationship. However, the quantification of the starting concept did not increase the number of dynamic propositions in any of the structures. The second experiment indicated a preference for a cyclic concept map, primarily for structural reasons. The studies, the theoretical background, and the implications of the findings are discussed.

1 Introduction

Most of the studies conducted on the subject of Concept Maps (CMaps) have been concerned with the practical application of the tool rather than its evaluation. The aim of this research is to investigate the tool itself and provide a better understanding of the capabilities and limitations of CMaps.

The basic premise of concept maps has been the representation of knowledge in a hierarchical form. Some researchers have questioned the hierarchical structure as the only means of linking concepts together (Ruiz-Primo & Shavelson, 1996). For example, one suggestion has been that the structure of the map should follow the structure of the knowledge and not the other way around.

We propose (see theoretical section) that the structure of the map influences the type of relationships that are likely to be constructed in a proposition that links two concepts together. The prediction is that the Cyclic CMap (where concepts feed into one another in a closed loop), rather than a hierarchical structure, is more likely to generate dynamic propositions. Further, it is hypothesized that the expression of concepts in a more quantified form will also increase the probability of dynamic propositions. It is reasoned that using a quantified concept such as “number of cars,” instead of the concept “cars,” is more likely to lead to another quantified concept like “number of accidents.” The attempt to link them may increase the likelihood of propositions that account for the relationship between the two constructs as one of them changes. Finally, it is predicted that a Cyclic CMap will be preferred to a hierarchical CMap structure.

This paper begins with a review of the literature on Cmaps. The theoretical arguments and the experimental hypotheses are then presented, followed by a description of the methodology and results of the experiment. Finally, the hypotheses are discussed and the conclusions of the study are presented.

2 Concept Map Research

A CMap (Novak & Gowin, 1984; Novak, 1998) represents a collection of interconnected concepts with specified relationships between pairs of concepts identified on the links connecting them. The nodes and their relationships are organized in a certain structure in a CMap. Initially, the hierarchical structure in concept mapping was strongly encouraged (Novak, 1998). However, this inclination was questioned by Ruiz-Primo and Shavelson (1996) and Hibberd, Jones, and Morris (2002), among others. Several types of structures have been discussed such as hierarchy, chain, spider-maps, and networks that could be closer to the actual mental representation of the knowledge embedded in one’s long-term memory. Safayeni, Derbentseva, and Cañas (2003) argued that a CMap with a cyclic structure encourages representation of dynamic relationships between concepts and stimulates systems thinking. There is no strong agreement among researchers on the type of structure a CMap should have, although it has been acknowledged that the structure of a map should suit the content.

Research on CMaps has been done mainly in the context of the tool’s application in education and its usage in the knowledge management area. For example, Edmondson (1995) discussed the positive effect of the use of CMaps in the development of a problem-based veterinary curriculum. Willerman and MacHarg (1991) examined the use of CMaps as an “advance organizer” for eighth-grade students in a science unit. They reported significant differences in performance of a CMap group at the end of the unit over a control group that did not use CMaps. Soyibo (1995) described the use of concept mapping to identify differences in the presentation of the topic of respiration in six biology textbooks. The author suggested that the analysis of CMaps is an appropriate way of comparing the textbooks. Markow and Lonning (1998) tested the effect of CMap construction in college chemistry laboratories. They reported that students had a strong positive attitude toward the use of Cmaps, despite the lack of difference in performance on multiple choice assessment tests between the experimental and control groups.

CMaps have also been used to capture the knowledge of experts. For example, Ford et al. (1991) described the knowledge acquisition tool ICONKAT that uses CMaps along with Kelly’s (1955) repertory grid to elicit knowledge from experts. Ford et al. (1996) described a nuclear cardiology expert system, NUCES, in which a system of CMaps created during the knowledge elicitation stage is also used as the navigation system for its explanation component. Coffey et al. (2003) reported on a performance support system with embedded training for electronic technicians based on CMaps. Hoffman et al. (2002) empirically demonstrated the effectiveness of using concept mapping as part of a methodology for eliciting expertise.

The use of CMaps for evaluation of students’ knowledge has been reported by many researchers. For example, Williams (1998) and Markham and Mintzes (1994) compared CMaps constructed by novices to those made by experts. Both studies reported significant differences in the CMaps of experts and novices; whether the findings were based on subjective comparisons (Williams, 1998) or numerical scores (Markham & Mintzes, 1994). The authors argued that CMaps are able to capture differences in the knowledge and understanding of the subject matter, and they can be used as a research and evaluation tool (Markham & Mintzes, 1994). Generally, there is a positive attitude toward using CMaps as an evaluation tool, because it is argued that CMaps are powerful in revealing students’ misconceptions (e.g., Roberts, 1999; Kinchin, 2000). However, some authors warn against the lack of reliability and validity in concept mapping techniques and scoring practices, insisting on more research on the tool’s effects before it can be used for the formal assessment of students’ knowledge (e.g., Ruiz-Primo & Shavelson, 1996). In response to these criticisms, McClure, Sonak, and Suen (1999) compared six existing scoring methods of CMaps and found support for the validity of five of them as well as some degree of correlation among all six measures.

Two studies compared concept maps to other forms of knowledge representation with respect to learning new material. Lambiotte and Dansereau (1992) compared CMaps to lists and outlines such as those used for lecture aids, and assessed differences in students’ recall of the presented material. They reported no significant difference between the effect of CMaps and the other two lecture aid forms. Contrary to these results, Hall, Dansereau, and Skaggs (1992) reported a significant difference in the recall of material presented in the form of a CMap when compared to a normal text presentation for only one of the two subject domains tested. These findings raise more questions than they answer, especially regarding the usability and suitability of CMaps in different contexts.

Most of the studies conducted on the subject of CMaps have been concerned with the use of the tool rather than with an evaluation of the tool. The aim of the research effort presented here is to investigate the tool itself and provide a better understanding of the capabilities and limitations of CMaps.

3 Theoretical Argument and Experimental

3.1 Structure of the Map as a Means to Encourage Dynamic Representation

The concept map is a tool designed to identify and represent relationships between different concepts in a domain. Safayeni et al. (2003) distinguished between two types of relationships among concepts, static and dynamic. Static relationships reduce the uncertainty in the labels by connecting the concepts in a proposition, whereas dynamic relationships are concerned with covariation among the concepts.

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 hierarchical character of CMaps is a natural form for the representation of classifications and hierarchies.

A dynamic relationship between two concepts reflects and emphasizes the propagation of change in these concepts. The dynamic relationship shows how change in *quantity*, *quality*, or *state* of one concept causes change in *quantity*, *quality*, or *state* of the other concept in a proposition. In other words, a dynamic relationship reflects the functional interdependency of the two or more concepts involved. For a more elaborate discussion on static and dynamic relationships, see Safayeni et al. (2003).

As science has progressed, it has moved away from the creation of hierarchies and categorizations, and toward establishing functional relationships among concepts (Lewin, 1935). The greatest advances of science are represented in the form of dynamic relationships as embodied in the laws of physics and captured in the form of mathematical equations. Dynamic relationships among concepts might not be as well formulated in other domains of knowledge, making it impossible to represent them in the language of mathematics. However, if the dynamic relationships are established to some degree, then the representation of such relationships is possible using an ordinary language, although the loss of information is inevitable. If a CMap is to be considered a valid knowledge representation tool, it is important to investigate the CMap's ability to represent dynamic relationships.

Safayeni et al. (2003) argued that CMaps, while robust in representing static relationships between concepts, lack the potency for encouraging and representing dynamic relationships among concepts. The authors argued that this deficiency is mainly due to the endorsement of the hierarchical nature of CMaps. Reported analysis of 34,000 propositions extracted from various CMaps revealed that no more than 4% of these propositions could potentially be classified as dynamic.

At the same time, Safayeni et al. (2003) proposed Cyclic Concept Maps (Cyclic CMaps) as an extension to traditional Cmaps, to facilitate the representation of dynamic thinking in concept mapping. In its simplest form, the Cyclic CMap has a cyclic structure in which all concepts are connected in the form of a loop, each having one input and one output. In this structure, concepts are highly interdependent because of the cyclic nature of the relationships. A change in state of any concept affects the states of all other concepts. Therefore, Cyclic CMaps are considered to be an appropriate tool for representing knowledge of functional or dynamic relationships between concepts. High structural interdependence of the concepts in such maps represents a system of interrelationships rather than a collection of independent propositions, as often occurs in the hierarchical structures. Moreover, high structural interdependence of the concepts formed by a cyclic structure encourages the representation of dynamic relationships between concepts. Thus, the following hypothesis can be formulated.

H1 Structure effect: A cyclic structure encourages the construction of more dynamic relationships than does a hierarchical structure.

3.2 Quantification of Concepts as Another Possible Solution to Encourage Dynamic Representation

Safayeni et al. (2003) suggested that quantification of the starting concept in a map makes the concept more dynamic, and thus leads to the construction of more dynamic propositions. Quantification of a concept reduces variability with respect to the possible set of meanings the concept could potentially refer to, while drawing attention to the specific property of the concept that can change its value. Quantification of a concept makes reference to change much easier because it selects a single dimension of change for that concept. For instance, it is hard to imagine a change in the whole concept "soil," but it is much easier to imagine a change in the concept "quality of soil." In fact, when the quantifier "quality" is added to the concept "soil", one right away starts thinking about "quality of soil" being rated from good to bad or high to low, thereby setting this concept "in motion" and allowing it to change. Thinking about the change in the starting concept 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 starting concept. Therefore, the following hypotheses are formulated.

H2a Quantification effect: Quantification of the starting concept in the hierarchical structure will result in more dynamic propositions compared to a nonquantification condition.

H2b Quantification effect: Quantification of the starting concept in the cyclic structure will result in more dynamic propositions than that of a nonquantification condition.

A cyclic structure represents not just a collection of segregated propositions, but also a system of interconnected concepts on a given topic. The system representation and interconnectedness of concepts should appear intellectually more meaningful than a hierarchical representation of the same topic. Thus, the following hypothesis is formulated.

H3 Preference: When given a choice, subjects will prefer a cyclic over a hierarchical representation of the same topic.

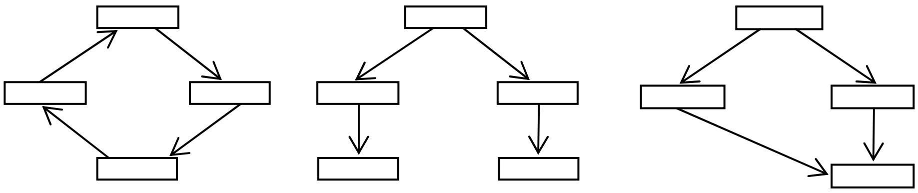
4 Experiment 1 (Map Construction)

The purpose of Experiment 1 was to investigate the structure and quantification effects on the dynamic nature of the constructed propositions by testing the first two hypotheses.

4.1 Method

4.1.1 Stimuli selection

Simple prototypes of cyclic and hierarchical structures were constructed to be used as stimuli, and are presented in Figure 1. The prototypes reflected the main properties of the represented structures, while having minimal complexity. Two variations of the hierarchical structure were included; a classical tree structure, which is rarely used in CMaps, and a cross-link structure, in order to provide a fair representation of a classical CMap. The unit of analysis in this experiment was a proposition. The number of propositions was kept the same in all three prototypes.



a) Cyclic structure prototype b) Hierarchical tree structure prototype c) Hierarchical cross-link structure prototype

Figure 1: Prototypes of a) cyclic structure, b) hierarchical tree structure, and c) hierarchical cross-link structure

4.1.2 Subjects

The subjects for this study included 112 undergraduate students from the University of Waterloo. All were enrolled in the same course and were offered a partial credit toward their course mark for their involvement in the study.

4.1.3 Procedure

Subjects participating in Experiment 1 entered concepts and linking phrases in one structure prototype provided to them. The top-most box of the structure had a concept written in it, whereas all other boxes and arrow labels were blank. For each of the three structure prototypes, quantification and nonquantification conditions were tested, for a total of six conditions. All maps of nonquantification conditions started with the concept "plant"; and all maps in quantification conditions started with the concept "number of plants". Subjects were assigned randomly to the conditions.

4.1.4 Measures

Each concept map constructed by the subjects was analyzed and assigned a dynamic score. The dynamic score reflected the number of dynamic propositions in the map, and ranged from 0 to 4.

In order to analyze the propositions, the maps were broken down into individual propositions consisting of two concepts and a linking phrase between them. Each proposition in every map was analyzed individually and separately from the rest of the map. Each proposition was evaluated to determine whether it reflected a dynamic relationship between the concepts involved. Relationships that reflected how change in the quantity, quality, or state of one concept resulted in a change in the quantity, quality, or state in the other concept were classified as dynamic. For example, the propositions {"More green and bright colors" <reduce> "Sense of anxiety and stress"} and {"Planting seeds" <will lead to> "Growth and maturation of the plant"} were classified as dynamic. For more information on the scoring of the propositions please contact the first author.

The scoring of all 448 propositions was performed two times separately. Each time the order of the propositions was randomized, and the information about the map was hidden from the scorer. A high degree of reliability was obtained in the blind rescoring; only 6% of the total number of scores deviated.

4.2 Results

The results for testing hypothesis H2 are reported first, followed by the test of hypothesis H1 and hypothesis H3. Hypothesis H2 was tested first so that the data could be combined to test hypothesis H1.

4.2.1 Testing hypothesis H2

A visual examination of the data for all six conditions suggested that there was not much difference between quantified and nonquantified propositions in any of the structures. Because the requirements of normality of the sampling distribution and equality of the variances were not met, nonparametric statistical tests were applied. A Wilcoxon-Mann-Whitney one-tailed test showed no significant differences between quantification and nonquantification conditions in all three structural prototypes. The obtained p values were 0.432, 0.312, and 0.396 for the cyclic, cross-link, and tree structures, respectively.

Therefore, hypotheses H2a and H2b were rejected. That is, the quantification of the starting concept does not increase the number of dynamic propositions in the cyclic structure or in either of the forms of the hierarchical structure.

4.2.2 Testing hypothesis H1

To analyze the structure effect on the dynamic nature of the constructed propositions, data from the quantification and the nonquantification conditions of the same structure were combined because there was no statistical difference between them. The Kruskal-Wallis test was administered for the among groups comparison, the obtained value $p < 0.001$. This result yielded that at least one group among the three is significantly different from at least one other group in the sample. To achieve pair-wise comparison, the Wilcoxon-Mann-Whitney test was performed. For the cyclic – tree comparison $Z = -4.403$ ($p < 0.001$); for the cyclic – cross-link comparison $Z = -3.407$ ($p = 0.001$).

The analysis provided strong support for hypothesis H1, which states that the cyclic structure encourages the construction of more dynamic propositions than does either of the hierarchical structures. It is worth noting that a significant difference was achieved not only for the case of tree structure, but also for the case of cross-link structure.

Because both the tree structure and the cross-link prototypes are based on the hierarchy of concepts, there was no reason to expect them to produce different results. Indeed, the Wilcoxon-Mann-Whitney test found no statistically significant difference ($p = 0.25$) between these two prototypes.

5 Experiment 2

The purpose of Experiment 2 was to identify any subjective preference for the cyclic structure over the hierarchical structure. Similar to Experiment 1, the cyclic structure was compared to the two variations of the classical concept map hierarchical structures (the tree and the cross-link).

5.1 Method

5.1.1 Stimuli selection

CMaps for Experiment 2 were selected from the pool of CMaps constructed by subjects in the first experiment. Maps with the highest dynamic score were picked out for each of the structural prototypes. Care was taken to select maps with similar content from the three structural representations. Using similar maps reduced the variability in the selection due to nonstructural effects. In the experiment each structural prototype was represented by one map. The three chosen maps were used to generate pair-wise comparison conditions.

5.1.2 Subjects

The subjects for Experiment 2 included 72 students from the University of Waterloo. All were enrolled in the same course and were offered a partial credit toward their course mark for their involvement in the study.

5.1.3 Procedure

In Experiment 2, subjects selected the more "interesting" map between the two presented to them, and then explained their choice. The three conditions that were tested in this experiment consisted of pair-wise comparisons among cyclic, cross-link, and tree structure prototypes. Twenty-four subjects were assigned randomly to each of the conditions.

5.1.4 Measures

Subjects made a binary choice between the two maps presented to them. The number of times each type of map was selected in a given comparison condition was counted. This represented a selection score for each structure in a given comparison condition.

Subjects were also asked to provide reasons for their choice. These responses were analyzed and categorized based on the similarity of their meaning. All reasons given by the subjects for all three comparisons were grouped into three categories:

- reasons that addressed the structural properties of the maps;
- reasons that commented on the informative properties of the structures;
- reasons that pointed out differences in the content of the maps or specific words used.

The separation of the comments into these three categories was helpful in attributing a preference for a certain prototype to specific properties of that prototype.

5.2 Results and Discussion

5.2.1 Cross-link – tree comparison

In the cross-link – tree comparison condition, 58% of the 24 subjects tested selected cross-link as more "interesting." A Binomial test indicated no significant difference in preference between the cross-link and tree structures ($p = 0.541$) conditions, so the data were combined.

Qualitative analysis was conducted on the subjects' comments. Pros and cons for each of the structures appeared in the subjects' comments, and the distribution of these among the three categories is reported in Table 1.

Category of comments	In favor of cross-link	In favor of tree	In opposition to cross-link	In opposition to tree
Structural properties	10 (37 %)	7 (28 %)	4 (80 %)	9 (82 %)
Informative properties	5 (19 %)	11 (44 %)	1 (20 %)	0
Content	12 (44 %)	7 (28 %)	0	2 (18 %)

Table 1: Distribution of number of comments among the categories for the cross-link – tree comparison

A chi-square test showed that comments in favor of either cross-link or tree were distributed virtually randomly among the categories of comments ($p = 0.527$, $p = 0.236$ for cross-link and tree, respectively). It is worth pointing out that the significant number of comments in favor of a map is related to the content in both cases. This could be explained by the sufficient degree of similarity in the two structural variations that forces subjects to retreat to the minute differences in the wording. The number of comments in opposition to either structure was too low for any meaningful statistical treatment.

The two analyses above indicate that the choice between the cross-link map and the tree map was random. No significant preference or perceived difference between these two variations was found. This result was not surprising, because the cross-link was considered to be a variation of the tree structure. Therefore, further analysis was conducted to examine the comparison of the cyclic structure to both forms of hierarchy, combining the data for cross-link and tree structures.

5.2.2 Testing hypothesis H3

Out of the 48 subjects tested, 79% selected the cyclic structure as more “interesting.” The result of the Binomial test between cyclic and hierarchical structures was highly significant ($p < 0.001$). This illustrates that the cyclic structure was not only able to represent dynamic relationships, but was also more appealing to people.

Based on the above findings, hypothesis H3 was supported. That is, there was a strong subjective preference for the cyclic structure prototype over the hierarchical structure. The distribution of the comments given by the subjects to support their preference among the categories is presented in Table 2.

Category of comments	In favor of cyclic	In favor of hierarchy	In opposition to cyclic	In opposition to hierarchy
Structural properties	57 (84 %)	7 (39 %)	3 (75 %)	22 (67 %)
Informative properties	11 (16 %)	9 (50 %)	1 (25 %)	11 (33 %)
Content	0	2 (11 %)	0	0

Table 2: Distribution of number of comments among the categories for the cyclic – hierarchy comparison

From the numerical analysis of the comments favoring a cyclic CMap, it was clear that subjects attributed their preference to the structural properties of the cyclic CMap. In fact, the cyclic structure was described as “cycle clearly shows how each concept is related to the other,” “cycle is a self-sustained system,” “complete circle,” “cyclical relationships make more sense,” “cyclic structure is more intuitive,” “circular pattern shows continuous process,” and so on. Also, structural weaknesses of the hierarchy were major reasons reported in opposition to selecting a hierarchical map. Comments such as “in <hierarchy> there seem to be missing relationships,” “in <hierarchy> structure there are ‘dead ends’,” “<hierarchy> structure’s flow is only one way,” and “it does not allow us to see the whole picture” were reported as weaknesses of the hierarchical structure. On the other hand, the subjects who selected hierarchy for their preference justified their choice by comments such as “<hierarchy> is laid out in a more hierarchical manner,” and “<hierarchy> is straight forward and easy to understand.”

It is worth pointing out that only 2 out of 123 comments were directed toward the content of the maps in the cyclic versus cross-link and tree selection conditions. This suggests that there were sufficient structural and informative differences between the cyclic and the two hierarchical prototypes.

6 Conclusion

The predicted effect of the structural properties of a map on the dynamic nature of the propositions was supported by the experimental results. As was expected, the cyclic structure produced significantly more dynamic propositions than either form of hierarchy. Quantification of the starting concept in a map was expected to increase the number of dynamic relationships, however, no effect was observed in the experimental data. One plausible explanation is that the phrase “number of plants” was interpreted as “the population of plants” and not as the “quantity of plants,” as was intended by the researchers. The first interpretation is not a quantified version of the concept “plants,” but rather refers to a group of plants. The second interpretation is a quantified version of the concept “plants,” and it refers to the property of quantity. The question of the concept quantification effect on the characteristics of the propositions can be further explored by quantifying a concept more explicitly, for example, by using the phrase “increasing the number of plants.” This version of concept quantification is less likely to lead to misinterpretations and may allow the true effect of concept quantification on the property of the constructed linking phrases to be observed.

As was expected, subjects preferred the cyclic structure over the hierarchical structure. The majority of the subjects found the cyclic CMap more “interesting” than the hierarchical map. The analysis of reasons provided by the subjects suggested that this preference was due to the structural properties of the maps. Eighty-four percent of the reasons for choosing the cyclic structure were attributed to its structural characteristics whereas 67% of the reasons for not choosing the hierarchy were attributed to the hierarchy’s structural characteristics.

The data show that the form of representation influences the content of the constructed CMap. Moreover, a cyclic structure leads to an increase in the representation of functional dynamic relationships between concepts. Despite some authors’ arguments that CMaps are not purely tree-like structures due to the use of cross-links, the present study shows no difference between a pure tree structure and its cross-link variation on any of the measures used. This suggests that CMaps need more drastic changes than a mere use of cross-links to be suitable for capturing and representing knowledge of dynamic relationships. Safayeni et al. (2003) proposed such a change, called Cyclic Cmaps. The present study provides experimental support for the Cyclic CMaps extension as an appropriate tool for representing dynamic relationships in a single system.

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UN ENFOQUE CONSTRUCTIVISTA PARA USO DE MAPAS CONCEPTUALES EN EDUCACIÓN A DISTANCIA DE PROFESORES

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Resumen. Este trabajo presenta una propuesta de utilización de los mapas conceptuales en la formación de profesores a distancia usando el software CmapTools del Institute for Human and Machine Cognition, dentro de un paradigma constructivista. Nuestra propuesta utiliza como base teórica la Epistemología Genética de Jean Piaget y, en especial, la teoría de las Implicaciones Significantes para la construcción de categorías de análisis de los mapas producidos por los profesores. Este análisis está centrado en las relaciones entre conceptos establecidos por los profesores a través de las frases de enlace en los mapas.
Palabras-clave: mapas conceptuales, epistemología genética, educación a distancia, formación de profesores.

1 Introducción

Durante los últimos años, programas especiales del Ministerio de Educación (MEC) de Brasil han promovido cursos de formación continua de profesores para atender una demanda creciente de metodologías que integren las tecnologías de información y comunicación en el trabajo de profesores de escuelas públicas. El Programa Nacional de Informática en la Educación (Proinfo/Secretaría de Educación a Distancia/MEC) lanzado en 1997, dio inicio a un proyecto de informatización de escuelas públicas, promoviendo, entre otras actividades, la compra de equipos e invirtiendo en la creación de Núcleos de Tecnología Educativa (NTEs) en los que profesores de escuelas públicas han sido instruidos en cursos de especialización para actuar como Profesores Multiplicadores, planeando y desarrollando acciones de formación en escuelas de la región atendida por cada NTE.

Actualmente, la demanda de cursos semipresenciales y a distancia de formación inicial (licenciaturas) y continua (post-grado) de profesores ha sido incentivada por políticas gubernamentales tales como la creación de los Centros de Formación Continua de la Secretaría de Educación Infantil y Fundamental del MEC, el Programa Nacional de Incentivo a Formación de Profesores de Enseñanza Media (ProIfem).

La *Universidade Federal do Rio Grande do Sul* (UFRGS, Brasil), por medio del Laboratorio de Estudios Cognitivos (LEC/Instituto de Psicología), ha ofrecido, desde 1997, cinco cursos de Especialización (360 horas), dos cursos de Perfeccionamiento (180 horas) y varios cursos de extensión en convenios con las Secretarías Estatales de Educación a través del Proinfo. Además, ha participado, en asociación con el Núcleo de Informática Aplicada a la Educación (NIED/Unicamp), en el proyecto Multilateral "Red Telemática para Formación de Educadores: Implantación de Informática en la Educación y de Cambios en las Escuelas de Países de América Latina" y en el Centro Virtual Interamericano de Cooperación Solidaria para la Formación de Profesores (http://www.nied.unicamp.br/oea/ y http://oea.psico.ufrgs.br). Estas acciones han ofrecido la oportunidad al equipo del LEC de desarrollar ambientes para formación de profesores y realizar estudios empíricos sobre ellos, tanto de la formación inicial (Basso, 2003) como de la continua (Nevado, 2002), así como del paradigma de investigación sobre aprendizaje e Internet (Nevado et al, 2001).

Nuestro objetivo en este trabajo es ofrecer una contribución de herramientas y métodos para cursos a distancia de formación de profesores que favorezcan el conocimiento sobre el proceso del aprendizaje humano. En los siguientes párrafos presentaremos: una breve descripción de los mapas conceptuales acompañada por nuestra concepción al respecto de los mismos; el software CmapTools; la propuesta de trabajo que fue realizada y produjo los datos que usamos para el estudio; una propuesta de categorías de análisis de los mapas conceptuales y las cuestiones de investigación que devienen de esta propuesta.

2 Mapas Conceptuales

Novak (2003) define el mapa conceptual como una herramienta para organizar y representar conocimiento. El mapa conceptual, basado en la teoría del aprendizaje significativo de Ausubel (2000), es una representación gráfica en dos dimensiones de un conjunto de conceptos construidos de tal forma que las relaciones entre ambos sean evidentes. Los conceptos aparecen dentro de cajas en los nodos del grafo al tiempo que las relaciones entre los conceptos se especifican a través de ***frases de enlace*** en los arcos que unen los conceptos. A dos o más conceptos conectados por frases de enlace, creando una unidad semántica, se le llama proposición. Las proposiciones son una característica particular de los mapas conceptuales si los comparamos con otros grafos similares, por ejemplo los mapas mentales. Según Novak (1984) el eje vertical expresa un modelo jerárquico para los conceptos en el que los más generales o inclusivos aparecen en la parte superior y los más específicos en las partes inferiores**.** Safayeni (Safayeni et al, 2003), no obstante, sostiene que los mapas conceptuales cíclicos, o sea, no jerárquicos, pueden ser más eficaces para una representación más dinámica del conocimiento, permitiendo una mayor posibilidad de configuraciones de un mapa conceptual, tanto en lo que se refiere a su topología como en el tipo de frases de enlace.

La profusa literatura disponible revela la necesidad de estudios sobre los mecanismos cognitivos involucrados durante el proceso de construcción de mapas conceptuales desde punto de vista de quien lo realiza. Safayeni (Safayeni et al, 2003) destaca el gran alcance de los estudios sobre los mapas conceptuales. En su revisión, la mayoría de estos estudios apenas hace una comparación de los mapas como organizadores de conocimiento con relación a otros tipos de representaciones como los textos, hipertextos etc. Jonassen (2000) relata estudios realizados sobre los usos más tradicionales de mapas conceptuales como forma de evaluar cuán próximo está el conocimiento de un estudiante al de un experto en el tema, a través de comparaciones entre mapas. En Brasil, Moreira (1997) afirma que los mapas conceptuales sirven para "enseñar usando organizadores previos, para hacer puentes entre los significados que el alumno ya tiene y los que precisaría tener para aprender significativamente el contenido de una materia, así como para establecer relaciones explícitas entre el nuevo conocimiento y aquél ya existente y adecuado para dar significados a los nuevos materiales de aprendizaje", en un abordaje que les atribuye a los mapas conceptuales el "poder" de estructurar el pensamiento del sujeto por comparaciones a modelos o aún por organizaciones de estrategias por parte del educador que le permiten al estudiante entender como "precisa" pensar. Cabe destacar que esta referencia da prerrogativa explícitamente a la enseñanza.

Para Novak (1998), conceptos son regularidades percibidas en eventos u objetos de tal forma que los mismos, los conceptos, y las proposiciones son los bloques de construcción de conocimiento en cualquier dominio. Para él, un aprendizaje significativo exige las siguientes condiciones: la materia a ser aprendida debe estar conceptualmente clara y presentada en un lenguaje y con ejemplos que puedan ser relacionados con lo que el aprendiz tiene como conocimiento previo; el aprendiz debe poseer un conocimiento previo relevante (lo que para este autor, cualquier niño a partir de los 3 años de edad ya detenta virtualmente en cualquier dominio de conocimiento); y el aprendiz debe elegir aprender significativamente. De este modo, por intermedio del lenguaje, los aprendices procesan nuevas significaciones que deben estar organizadas progresivamente para poder afirmar su conocimiento. Así, Novak defiende la representación a través de mapas conceptuales como un dispositivo que puede ayudar en ese proceso, presentando una organización jerárquica que puede ser utilizada para la identificación de conceptos más generales y ayudando en la preparación de tareas de aprendizaje para la recepción de nuevos conceptos, más específicos. Esto confirma la adecuación de nuestra preferencia por los mapas. Sin embargo, un análisis de los términos y argumentos presentados nos suscita algunas preguntas:

- La materia que será aprendida debe estar conceptualmente clara ¿para quién? ¿Aquello que está claro para el profesor estará necesariamente claro para el alumno?
- ¿El lenguaje es anterior al proceso de conceptualización?
- Considerando los diferentes niveles alcanzados en un proceso de generalización, ¿cómo determinar una organización jerárquica? ¿qué es más general y qué menos general para un profesor y para un alumno?
- ¿Cómo llega un científico a la organización jerárquica de conceptos en un campo de conocimiento? ¿Esta se da a priori?

La idea piagetiana de concepto sitúa la representación a través de mapas conceptuales en un paradigma diferente a aquél establecido por la visión cognitiva de Ausubel y Novak. Para Piaget, un concepto resulta de la transformación de un esquema de acción en un proceso infinito de yuxtaposición de atributos por regulaciones sucesivas causadas por desequilibrios en los sistemas de significación del sujeto. Por lo tanto, las palabras que colocamos en las cajas de los mapas conceptuales (en general sustantivos) no son necesariamente, desde la perspectiva del sujeto, los conceptos. Aunque tales palabras puedan representarlos, son las relaciones construidas las que los delimitan en el ejercicio de atribución de significados solamente alcanzados por la interacción del sujeto con objetos en determinados contextos. Se opone, por lo tanto, a la visión de que una organización secuencial y correcta de estrategias, materia y actividades sea de por sí la garantía del aprendizaje de un concepto, por recepción.

Pues bien, si un mapa conceptual es, a priori, una representación, precisamos atribuirle un carácter de inconcluso, algo en proceso de transformación. Esto queda aún más evidente si estamos tratando de usarlo para acompañar procesos de construcción de conceptos, que es nuestra intención. Para Piaget, "un sistema conceptual, con efecto (y a fortiori sensorio-motriz etc), es un sistema tal que sus elementos se apoyan inevitablemente unos en otros, siendo al mismo tiempo abierto a todos los intercambios con el exterior.

Supongamos, por imposible, la construcción de un único concepto A, como punto de partida de una clasificación (...). Si fuera realmente un concepto, se opone entonces ya al concepto no-A, lo que constituye, desde el primer momento un sistema total y circular. En el caso, único real, de un sistema multiconceptual, es imposible caracterizar algún concepto sin utilizar los otros, en un proceso que es también necesariamente circular" (Piaget, 1996). Luego, no jerárquico. De este modo, en la dinámica de la construcción de un mapa conceptual podemos acompañar la representación del sistema de significaciones activado en un sujeto de tal forma que en él también reconocemos subsistemas que se relacionan apoyándose mutuamente en la construcción de esas significaciones.

Nos resta aún, responder a cómo los mapas conceptuales pueden ser útiles para tal propósito. Eso nos lleva, entonces, a darle el debido destaque al papel fundamental de las frases de enlace. Podemos concebir esas frases de enlace como funciones estructurantes del mapa, son ellas las que distinguen un mapa conceptual de otros tipos de representación semejantes. Jonassen (2000) ya resaltaba el esfuerzo, nada trivial, de escoger una frase de enlace que represente una relación entre dos conceptos tanto por el gran número de posibilidades como por la necesidad de posicionar tal relación en el contexto en que ese par de conceptos se presentan.

Nuestra respuesta, entretanto, necesita un contexto que presentaremos a continuación.

3 El *software* CmapTools

Escogimos el *software* CmapTools[1] (Cañas *et al.* 2000, 2004) como apoyo en la formación de profesores por las facilidades que ofrece para compartir y colaborar en la construcción de mapas conceptuales. A través de servidores públicos localizados en cualquier sitio en Internet, el programa permite de manera sencilla publicar mapas, haciéndolos accesibles a otros usuarios. Grupos de profesores pueden colaborar de forma sincrónica o asincrónica en la construcción de los mapas conceptuales almacenados en estos servidores (Cañas, 2000). El mapa conceptual se convierte en el "artefacto" sobre el cual se lleva a cabo la colaboración, y el resultado de la colaboración queda plasmado en el modelo construido. Esta característica del programa le distingue de otros ambientes, en los cuales la colaboración se limita a intercambio de mensajes de texto entre los participantes.

Adicionalmente, CmapTools provee facilidades para la crítica de mapas conceptuales, permitiendo la "revisión de pares" entre los profesores mediante anotaciones (*Annotate*), listas de discusión (*Discussion Threads*) y Sopas de Conocimiento (*Knowledge Soups*) (Cañas *et al.*, 2001). Las anotaciones permiten escribir en una esquela de tipo *post-it* un comentario sobre una sección del mapa seleccionada, y reducir esa esquela a un icono. En la Figura 1, el rectángulo amarillo es una anotación que se expande al pulsar dos veces el icono que aparece inmediatamente a su izquierda. A partir de este recurso, podemos añadir en cualquier punto del mapa, notas y comentarios sobre los conceptos, frases de enlace etc. Las listas de discusión se pueden agregar a cualquier nodo (concepto o frase de enlace) del mapa. Las anotaciones se utilizan para expresar comentarios puntuales, mientras que las listas de discusión permiten iniciar una discusión sobre una proposición en particular. En la Figura 1, la ventana de abajo muestra un mensaje que será adicionado a la lista de discusión a la que se puede acceder al pulsar el icono que aparece debajo del concepto "Alcorán, libro sagrado". Igual que las anotaciones, se puede tener más de una lista de discusión en el mismo mapa. Las sopas de conocimiento permiten la colaboración a nivel de proposiciones: durante la construcción del mapa, el programa lo descompone en proposiciones que el usuario puede hacer públicas, con lo cual son agregadas a la "sopa" del tema sobre el cual se está colaborando. El programa entonces le muestra al usuario proposiciones de otros usuarios similares a las que este publicó., las cuales puede usar para mejorar su mapa, o las que puede criticar ó cuestionar agregándole una lista de discusión.

El sistema de "permisos" de los servidores permite establecer que usuarios tengan autorización para "anotar" el mapa de otro usuario, sin tener permiso para modificarlo (Cañas, Hill, Lott, & Suri, 2003). De esta forma se puede organizar un ambiente donde los estudiantes pueden agregar comentarios mediante anotaciones y/o listas de discusión a los mapas de colegas sin poder alterar su contenido. Igualmente, para el trabajo colaborativo en grupos, CmapTools permite crear carpetas para cada grupo donde todos los estudiantes del grupo tiene autorización para modificar los mapas y recursos dentro de la carpeta.

Las facilidades que ofrece CmapTools para compartir los mapas mediante servidores, colaborar en la construcción de los mapas de forma sincrónica o asincrónica, y las herramientas para comentar y criticar mapas de otros, unidos al hecho de que el software se encuentra en portugués, formaron la plataforma necesaria pero los cursos a distancia y para llevar a cabo el estudio que aquí reportamos.

[1] CmapTools está disponible para uso educativo en http://cmap.ihmc.us.

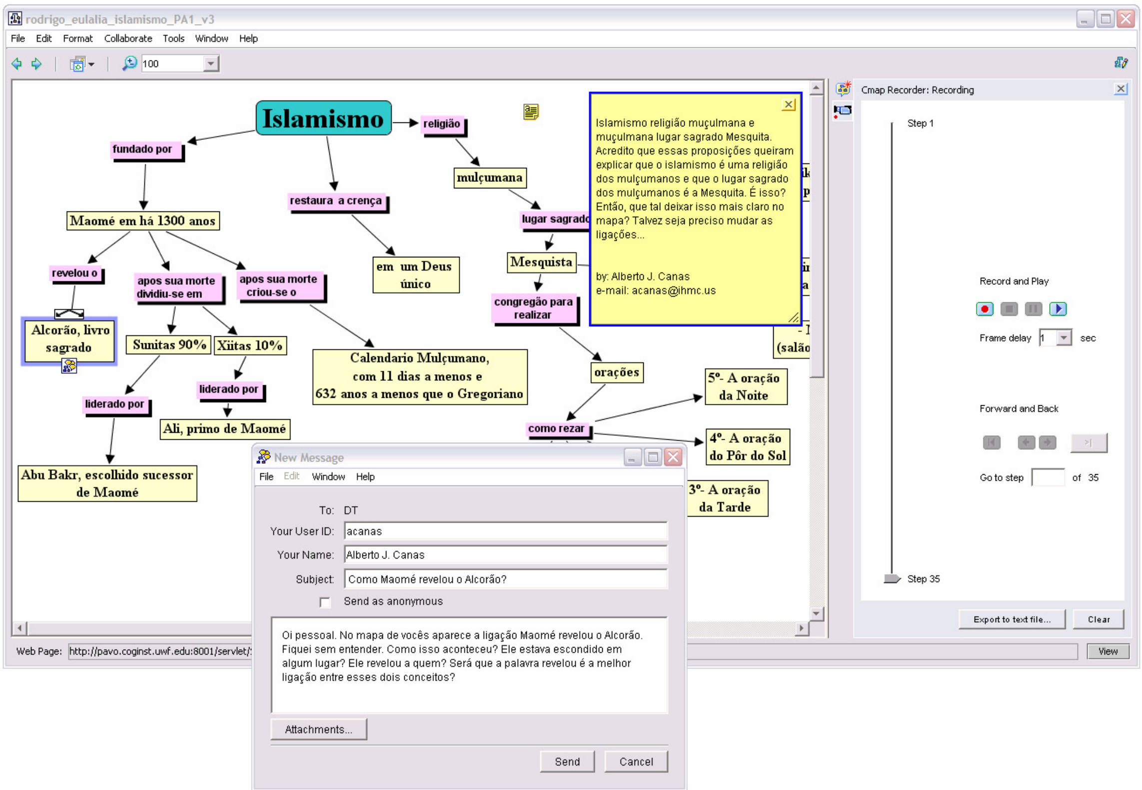

Figura 1. Mapa conceptual construido con CmapTools y herramientas.

4 Análisis de mapas conceptuales

Presentaremos, en la próxima sección, el resultado del análisis de un conjunto de mapas conceptuales, y sus respectivas modificaciones, construidos por profesores de escuelas públicas brasileras como parte de un Seminario del Curso de Especialización en Informática Educativa ofrecido por el Laboratorio de Estudios Cognitivos de la Universidad Federal de Río Grande do Sul (LEC/UFRGS).

La actividad propuesta en el seminario, consistía de la construcción de mapas conceptuales por parte de pequeños grupos de profesores, que expresasen su conocimiento acerca de un tema de su elección. Cada grupo estaba formado por aproximadamente 15 profesores en formación y un docente del LEC/UFRGS responsable por el seminario. Esos mapas, conceptuales fueron publicados en un servidor de mapas o transformados en figuras y publicados en páginas HTML en los *webfolios* de los grupos. Cada uno de los profesores recibió la tarea de analizar, preguntar y proponer modificaciones en los mapas de otros dos colegas, usando un foro de discusión abierto para cada tema. Los docentes del LEC responsables por cada grupo hicieron intervenciones proponiendo consideraciones y categorías de análisis que les permitieran a los profesores acceso a informaciones sobre el contenido abordado en el mapa con la intención de provocar desequilibrios en los sistemas de significación de cada profesor en formación. El seminario tuvo una duración de 45 días y fue realizado totalmente a distancia. Un número aproximado de 3 versiones de cada mapa conceptual fue producido por los profesores.

5 Categorías de análisis de los mapas conceptuales

Para Piaget (Piaget & García, 1989), desde los niveles más elementales de pensamiento existen implicaciones entre significaciones. No se trata de conocimientos relevantes según criterios externos, pues las significaciones son atribuciones del sujeto resultantes de sus asimilaciones de los objetos. En el caso de la construcción de mapas conceptuales, las inferencias del sujeto al implicar, en el conjunto CONCEPTO 1 – FRASE DE ENLACE – CONCEPTO 2 (anteriormente definidos como proposición), una relación entre los dos conceptos es, en última instancia (más general), una implicación significante. Creemos que al evaluar los niveles de implicaciones significantes tenemos buenos indicadores para el análisis de los mapas conceptuales. Pasaremos, en los próximos párrafos, a la construcción de categorías de análisis de las frases de enlace insertas en el sistema de relaciones de un mapa conceptual. También es necesario destacar que, las definiciones a continuación son el resultado de una adaptación de las definiciones de Piaget & García con la intención de discutir y analizar los mapas y especialmente, las frases de enlace, para producir posibles intervenciones/alteraciones que den como resultado la producción de nuevos observables para los sujetos involucrados.

Una ***implicación local*** puede ser definida como el resultado de una observación directa, o sea, aquello que se puede registrar del objeto apenas por la observación de su contexto y de sus atributos. De cierta forma, una implicación local puede caracterizar un objeto sin, por ello, actualizar el conocimiento sobre el mismo. Este es el caso de proposiciones en un mapa conceptual que usualmente usan verbos de enlace como "es", "tiene" etc. Entre tanto, el uso de frases de enlace "es" y "tiene", por ejemplo, no significa necesariamente una implicación local.

Una ***implicación sistémica***, a su vez, inserta las implicaciones en un sistema de relaciones en el cual las generalizaciones y propiedades que no son directamente observables (ya sea en la acción o en la percepción) comienzan a aparecer. En este sentido las diferenciaciones no son más apenas percibidas a partir del objeto, son deducidas a partir del mismo o de la acción sobre el mismo. Sin embargo, las coordinaciones del individuo todavía no crean una comprensión de las razones de estas implicaciones y sí un conocimiento aún procedural, obtenido paso a paso en la construcción de las implicaciones. La indiferenciación entre generalidad y necesidad es otra característica de este tipo de implicación. En los mapas, podemos notar sistemas de relación (generalmente jerárquicos) en los que hay implicaciones entre los conceptos considerando causas y consecuencias sin llevar aún a explicaciones y/o justificaciones. ¿Cómo? ¿Por qué? Estas son preguntas que aún no tienen respuestas.

Finalmente, una ***implicación estructural*** amplía las anteriores una vez que da explicaciones de las razones que llevan a realizarlas. Las generalizaciones son ahora relativas al propio objeto y se refieren a lo que se puede afirmar sobre el mismo y no necesariamente sobre su clase más general. Piaget menciona la comprensión endógena de las razones y el descubrimiento de las relaciones necesarias (Piaget & García, 1989). Así, más que un conocimiento de causas y consecuencias, las implicaciones estructurales establecen qué condiciones (en el sentido lógico) son imprescindibles para las explicaciones, diferenciándolas de aquellas que son apenas suficientes. En el caso de los mapas conceptuales, esto puede observarse en los ciclos de determinados subsistemas de significaciones.

6 Aplicando las categorías

Los dos ejemplos siguientes procuran describir un proceso de análisis usando las categorías anteriores y sirven de ilustración para el tipo de análisis que puede ser realizada a partir de las etapas de construcción de los mapas conceptuales usando los niveles de implicaciones significantes que describimos.

6.1 Ejemplo 1. Asunto: ¿Qué es moda?

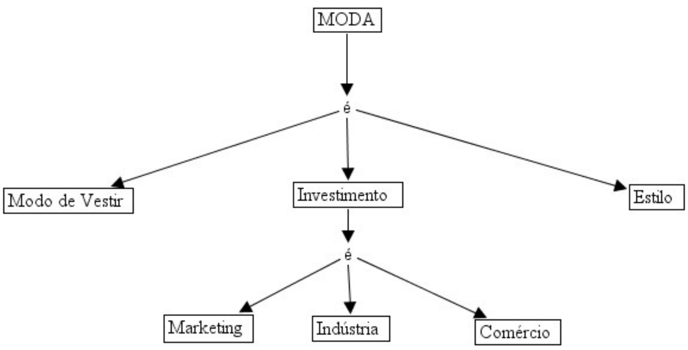

Figura 2. Parte del primer mapa conceptual sobre Moda

Si analizamos este primer sistema de relaciones a partir del concepto MODA, tenemos dos niveles de relaciones. A saber, MODA es MODO DE VESTIR, INVERSIÓN *(INVESTIMENTO)* y ESTILO; e INVERSIÓN *(INVESTIMENTO)* es MARKETING, INDUSTRIA y COMERCIO. Estas implicaciones procuran caracterizar el concepto MODA para definirlo usando otros conceptos. En este caso, el enlace "es" asume el papel de elemento aditivo, o sea, adiciona atributos al concepto MODA, pero no parece producir ninguna implicación que relacione los conceptos en un sistema. Podríamos clasificar este sistema de relaciones como implicaciones locales.

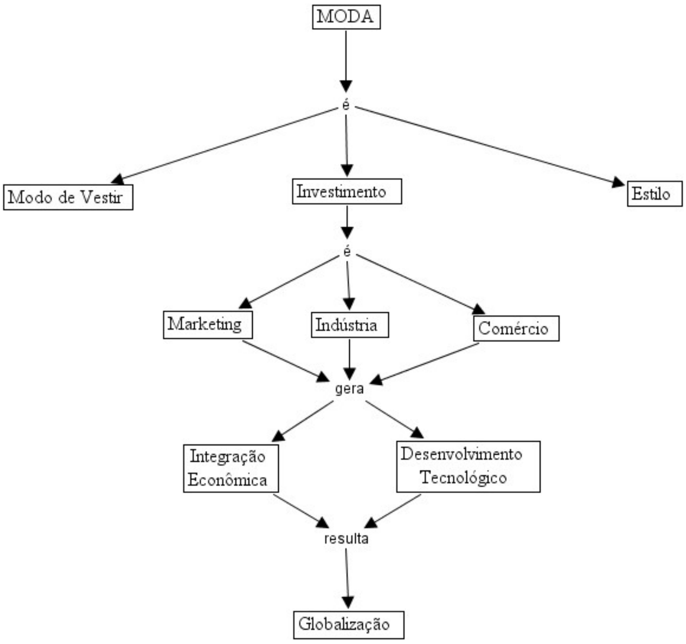

Figura 3. Parte del mapa conceptual modificado sobre Moda

La adición de elementos al sistema anterior revela una mayor diferenciación de las ideas que definen el concepto MODA mostrando sus consecuencias o derivaciones. Las frases de enlace "genera" y "resulta" le otorgan al sistema, y no de forma aislada, una nueva configuración en la que se puede percibir un progreso en la diferenciación del concepto moda. Sin embargo, aunque se pueda inferir, por ejemplo, que existe relación entre el concepto GLOBALIZACIÓN *(GLOBALIZAÇÃO)* y el concepto MODA, ello no está explícito. Tampoco hay indicios de relaciones necesarias que puedan dar soporte al sistema. ¿Cómo el MARKETING o la INDUSTRIA generan INTEGRACIÓN ECONÓMICA *(INTEGRAÇÃO ECONÔMICA)*? ¿Por qué el DESARROLLO TECNOLÓGICO da como resultado GLOBALIZACIÓN? Faltan las razones, los porqué. Podemos creer aquí, un indicativo de implicaciones sistémicas. Podemos también notar que el sistema asume un modelo jerárquico pero con poca o ninguna indicación del carácter de mayor o menor especificidad de cada uno de ellos.

6.2 Ejemplo 2. Asunto: ¿De dónde viene el papel?

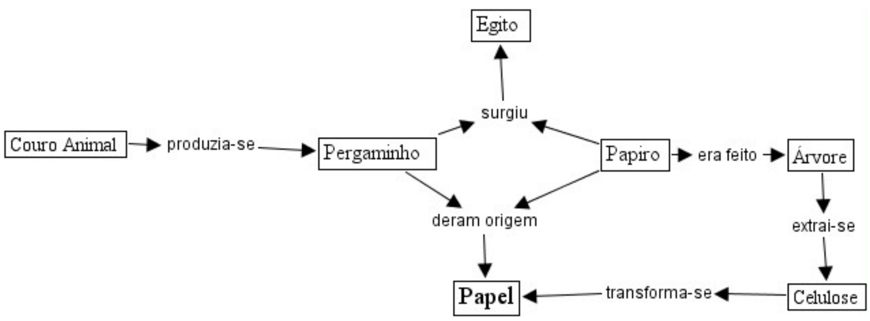

Figura 4. Parte del mapa conceptual sobre Papel

El sistema de relaciones presentado ya da muestras de una comprensión más sistémica de las implicaciones. Los enlaces "se producía", "dieron origen", "era hecho", "se extrae" y "se transforma" parecen indicar procedimientos para llegar al PAPEL, tanto en lo que se refiere a procesos históricos como físicos. Podemos observar aún que el ciclo PAPIRO – ÁRBOL – CELULOSA – PAPEL *(PAPIRO – ÁRVORE – CELULOSE – PAPEL)* da indicios de por qué el papiro dio origen al papel, pero aún quedan sin respuesta preguntas como las siguientes: ¿Cómo la celulosa se transforma en papel? ¿Cuál es la diferencia, entonces, entre papiro y papel?

Además del hecho de que las frases de enlace usan palabras que expresan procedimientos (procesos), podemos observar una configuración no jerárquica de implicaciones que, aún así, no incluyen las justificativas que indican estas implicaciones.

Es importante notar que, en esta parte del sistema de relaciones, el análisis que podemos realizar al respecto de las implicaciones puede ser elemento de soporte para la producción de nuevas acciones del sujeto en lo que se refiere a generar nuevos observables y, en ese proceso, las indicaciones de las preguntas a ser respondidas son de gran ayuda.

En la figura 5 (abajo) hubo una transformación en la topología del mapa indicando construcciones más sofisticadas con la intención de establecer nuevas "razones" para los enlaces presentados anteriormente. Sobre el análisis de la porción anterior, podemos notar que la pregunta **¿De dónde viene el papel?** fue dejada de lado para tratar el concepto PAPEL desde diferentes aspectos. El enlace PAPIRO – DIERON ORIGEN – PAPEL *(PAPIRO – DERAM ORIGEM – PAPEL)* no aparece más, siendo substituida, por lo que todo indica, por la adición del concepto TRANSMITIR INFORMACIÓN A TRAVÉS DE LA LENGUA ESCRITA *(TRANSMITIR INFORMAÇÃO ATRAVÉS DA LÍNGUA ESCRITA)* que transformó las otras implicaciones de los conceptos PAPEL y PERGAMINO *(PAPEL e PERGAMINHO)*.

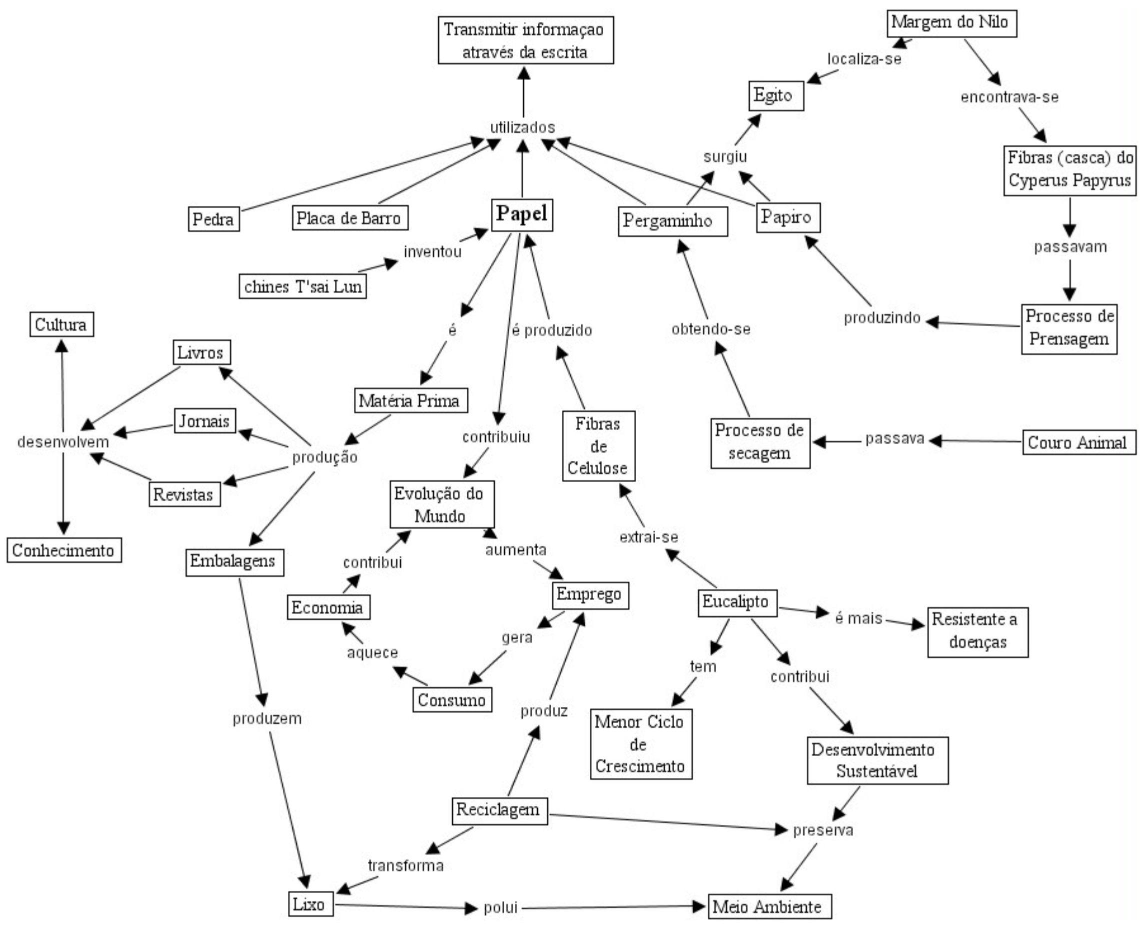

Figura 5. Mapa modificado sobre el Papel

En el ciclo que analizamos anteriormente (sobre el PAPIRO), fueron añadidos nuevos conceptos que modificaron las relaciones anteriores. Queda en evidencia que la búsqueda de justificativas para las implicaciones tuvieron como resultado una mayor comprensión del proceso, o sea, ya existen indicaciones de cómo el PAPIRO era producido (PROCESO DE SECADO) *(PROCESSO DE SECAGEM)*, dónde (MÁRGENES DEL NILO, EGIPTO) *(MARGENS DO NILO, EGITO)* y qué era necesario para su producción (FIBRAS DEL CYPERUS PAPYRUS). En ese aspecto, podemos clasificar ese conjunto de implicaciones como estructurales.

En conjunto, este último mapa trae ejemplos de todos los niveles de implicaciones que describimos anteriormente. En lo que atañe a las posibles intervenciones, cabe destacar que las mismas estarán de acuerdo con el objetivo del trabajo propuesto, o sea, dependiendo de la pregunta que será respondida el mapa conceptual puede dejar en abierto espacios para nuevas reflexiones que, por ahora, no son esenciales para lo que se está desarrollando. De este modo, si la pregunta estuviera relacionada a RECICLAJE DE PAPEL *(RECICLAGEM DE PAPEL)*, un análisis más consistente de las implicaciones relacionadas con este concepto (en este punto aún sistémicas), se tornaría necesaria.

7 Conclusiones

El fundamento tradicional de los mapas conceptuales se basa en una organización jerárquica de conceptos de acuerdo a la teoría de aprendizaje de Novak y Ausubel. En este artículo, exploramos los mapas conceptuales como la representación del conjunto de interrelaciones en que se apoyan los diferentes conceptos que contiene. Nuestro enfoque da énfasis a las frases de enlace entre los conceptos y las proposiciones por ellas creadas, en contraste con la estructura jerárquica, en el proceso de construcción de estas proposiciones por parte de alumnos y profesores. Presentamos nuestros esfuerzos iniciales en busca de una categorización de esas proposiciones, basada en la teoría piagetiana (Piaget & García, 1989), que pueda dar soporte a una evaluación del proceso de construcción de los mapas y también como una solución alternativa al problema que expusimos en la introducción de este trabajo. Finalmente nos referimos a algunas herramientas del software CmapTools que facilitan la construcción de los mapas y ofrecen apoyo a profesores y alumnos en la evaluación de la construcción de los mapas conceptuales.

Con esta propuesta, ofrecemos a la comunidad científica y profesores, un conjunto de herramientas que posibilite adaptaciones a su contexto de trabajo, generando discusiones sobre un paradigma educacional constructivista para la educación a distancia y en la formación de profesores. La necesidad de capacitación va en amento (actualmente hay una lista con más de 300 solicitudes para los cursos) y nuestras experiencias con el uso de mapas conceptuales ha sido aplicada en cursos del tercer grado, cursos de especialización, maestría y doctorado, además de los cursos de extensión para formación continua de profesores en UFRGS. Sin embargo, es indispensable una apropiación técnica profunda para sacar provecho de tales herramientas. En especial en el trabajo con alumnos entre diez y doce años, el uso de mapas conceptuales ha favorecido la observación y acompañamiento del proceso de conceptualización de los contenidos de los proyectos que desarrollan, los cuales se construyen de forma lógica (de la manera como piensa el alumno). Nuestras investigaciones apuntan hacia la construcción de un segundo nivel de análisis de los mapas conceptuales en el cual buscamos conocer las implicaciones que el cambio de las frases de enlace provocan en el sistema de significados representado. Con estos resultados, la colaboración entre nuestros grupos de investigación puede pasar a un nuevo nivel, donde una aproximación innovadora hacia los mapas conceptuales puede contribuir al desarrollo de nuevas herramientas que ayuden a los usuarios a evaluar los mapas y planear intervenciones.

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USING CMAPTOOLS SOFTWARE TO ASSIST IN PERFORMING JOB TASK ANALYSIS

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Abstract. This paper will describe one method used by the Navy to identify jobs, duties and tasks as part of the Job Task Analysis (JTA) process. It will also show the advantages of using knowledge acquisition and concept mapping techniques along with the elegant simplicity of CmapTools software to facilitate structured workshops. The implications of using concept mapping methodology for JTA are considered. Using anecdotal results from the Professional Mariner (PM) JTA workshop, the outcome shows that it is more efficient and more effective to achieve group consensus with the concept mapping and with CmapTools than with ordinary note taking and summarizing. Having a clear focus during the analysis optimized group performance. The concept-map oriented approach to grouping tasks in terms of major concepts (rather than linear lists of tasks) may add to current job understanding and a more meaningful approach to training. Having the projected maps to center their attention, the groups were able to get a firm grip on the task at hand. Those who participated were well informed and actively engaged in the concept mapping process. The facilitators and the mapping modelers were able to lead the groups to the desired end more quickly than with earlier JTA methods.

1 Introduction

New strategies for United States Navy (USN) training require fundamental changes in how the Navy educates and trains its workforce. The Navy's "Revolution in Training" launches new training ideas with a conceptual shift to apprentice-journeyman-master relationships. This approach is depicted in the USN Five-Vector Model (5VM) graphic. In the 5VM, each vector represents a specific path in a sailor's career. This online model is supported by a database, linking sailors to all aspects of a Navy career in specific job areas. The 5VM will link to Navy and civilian certification programs and training opportunities. Figure 1 is an example of a 5VM screen displayed for an Aerographer at the Journeyman level.

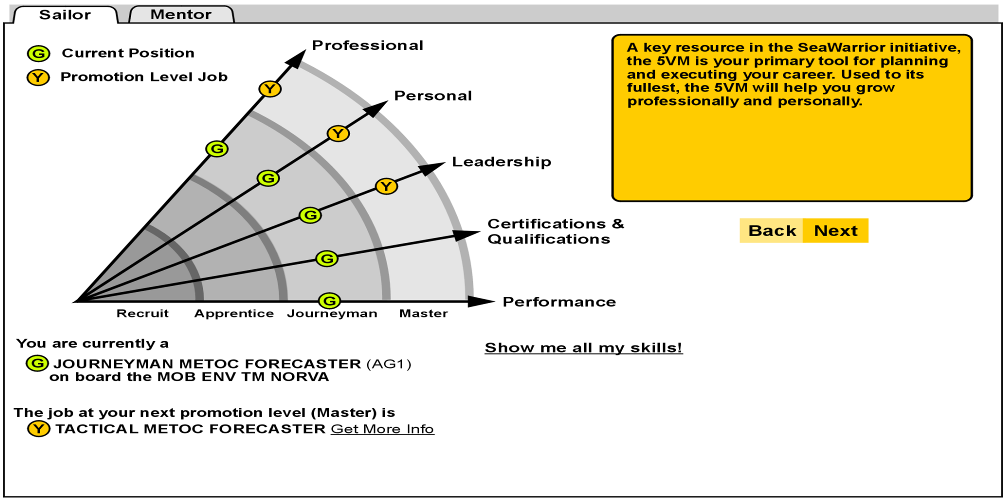

Figure 1: Example of a 5VM for the Aerographers Rating (AG)

1.1 Populating the 5VM

Task Force EXCEL (EXcellence through Commitment to Education and Learning) was established as the catalyst to begin the training revolution. The goal of Task Force EXCEL (TFE) was to create a roadmap for every single sailor on the 5VM, tying military qualifications to civilian certifications. TFE began the process to capture the job specific information needed to make the 5VM available online for every Navy occupation or "Rating." In populating the database behind the 5VM, TFE had the oversight for conducting job and training analyses though a series of workshops. The job data gathered was used to determine the quality of personnel, level of readiness, available resources, mission and manpower requirements.

1.2 Job Analysis Requirements.

The US government (US Department Of Labor 1978) deems job analyses necessary to support job selection procedures. The US Department of Labor (DOL) and the 1991 Americans with Disabilities Act (ADA) set the standards and guidelines on employee selection procedures. The DOL requires validation of personnel selection procedures by completing a job analysis. There are various ways to perform job analyses that will meet the DOL standards. A web search reveals that numerous companies provide job analysis services to help organizations meet the DOL and ADA standards. This paper will describe one method used to identify job, duties, and tasks as part of the Navy's Job Task Analysis (JTA) process. It will also show how concept mapping and CmapTools software can be used to improve this JTA process.

2 Job Analysis in the US Navy

TFE has used JTA for Navy Ratings, to identify jobs, duties and tasks, and the knowledge and skills necessary to perform a job successfully (Foster, Jones, and Becraft, 2000). In some cases, this process has been used to identify common tasks among Navy Ratings, in order to merge some Ratings and eliminate others. Many JTA workshops have been conducted to identify, by Rating, the jobs, duties and tasks of the Navy's sailors and the skills necessary to perform those tasks successfully. A primary focus of the USN JTA has been to look at a given Navy Rating and match it to a comparable civilian "community of practice" or "occupation" and its associated certification standards.

2.1 Performing Job Task Analysis in the Navy

JTAs initiated by the Naval Air Systems Command (NAVAIR) use a formal process involving scoping meetings, workshop brainstorming sessions, review, and analysis. This improved JTA workshop process identifies functional areas, jobs per function, duties per job, a list of job tasks, and levels of skill required for the jobs. This structure is similar in format to that of other process formats like Joint Application Development (JAD). Key people involved are similar to those identified in the JAD process (Yatco, 1999):

- **Executive Agent:** The executive who charters the project, the system owner. They must be high enough in the organization to be able to make decisions
- **Project Manager**: The military leader representing the Executive Agent. The Project Manager observes the process and answers questions about the project regarding scope, time, coordination issues and resources. This person will assist the facilitator in recognizing issues that can be resolved at the meeting and will take for action issues that must be resolved later.
- **Facilitator**: Provides the structure and keeps the group on task. The facilitator is responsible for identifying issues that can be settled at the meeting and issues that require further resolution.
- **Recorder:** Documents what takes place at the sessions and supports the facilitators and managers producing the final reports.
- **Participants:** Navy sailors directly or indirectly being affected by this project, who are experts in their field and can make recommendations about their work. They provide the input to the workshops.
- **Observers**: The military and civilian members of the upper echelon who work at varying levels to support that Rating. They are present to observe the proceedings and answer questions.

2.1.1 The JTA Workshop

The Navy brings together a group of specialists in a particular Rating (occupation) or group of Ratings. These Subject Matter Experts, or SMEs, represent all levels of proficiency, from apprentice to the master level. Key personnel in the Rating's chain of command are introduced to authenticate the workshop results. SMEs are assured that the results of their efforts will be summarized and reported to the executive agent at the top level of this group, usually an Admiral. The SMEs brainstorm, creating and scrubbing data, adding missing elements, and reviewing for relevant tasks and group consensus on those tasks. This process usually takes about six hours for each job. Each group generates up to 100 tasks and associates them with duties, then jobs, hierarchically. The discussion, identification, and labeling of duties and tasks is led by a facilitator. During the discussions, a recorder takes down all that is said

2.1.2 The JTA Workshop Mind Map

In developing the task statements, SMEs write data on yellow notes and paste them on the wall. Next, the SMEs group the notes put them into hierarchical order. Duty labels are assigned to each group, as the hierarchy begins to develop. The notes are grouped further by the duties associated with each job. Once the notes have been organized and SMEs have agreed to the placement and hierarchy, the recorder transfers the paper-based data from sticky notes to mind mapping software. The group breaks overnight to allow the recorder time to compile the information from the sticky notes. What is interesting about the JTA process using sticky notes is that the

SME grouping of the Jobs, Duties, and Tasks is similar to a concept map, with top down hierarchy. SMEs first visualize the data as a type of concept map. It is the recorder and facilitator who reinterpret the data as another type of image. The software used requires a very structured format that lays out information as a mind map. An example of a partial mind map is shown in figure 2.

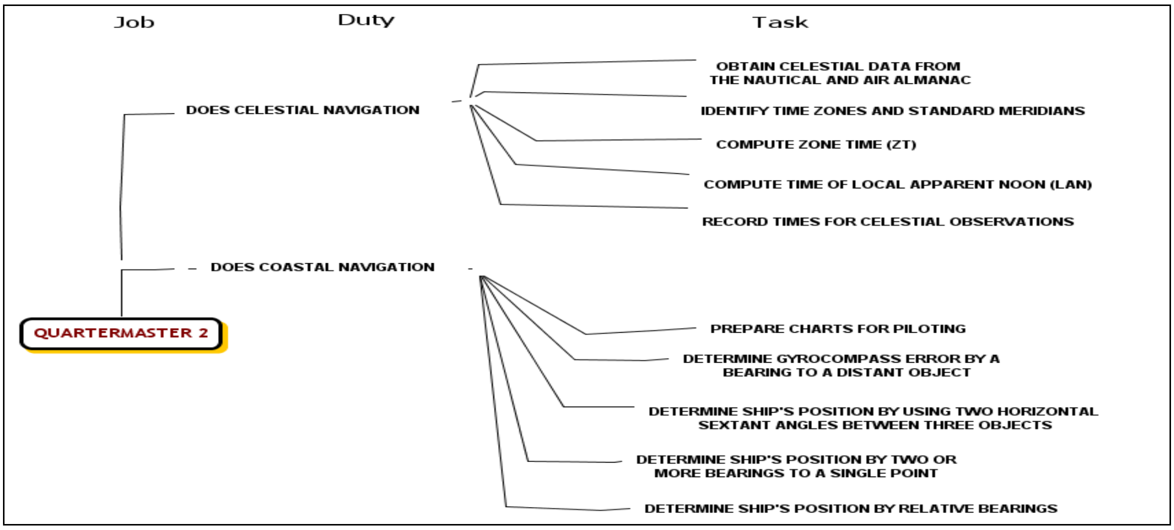

Figure 2: Partial mind map created using CmapTools

Mind map format (Buzan, 1991) focuses on a central point, with the most important ideas recorded closest to the center or hub. Ideas radiate out from the center, with relative importance diminishing as the distance from the hub increases. Its hierarchy radiates from the central point outward, rather than from the top down. The links between key concepts will be recognizable based upon proximity and connection (Buzan, 1991). Mind maps are circular in nature, extending in all directions from the center. CmapTools software was used to simulate part of a QM 2 mind map. (The actual mind mapping software was not available to draw the map, but CmapTools flexibility allowed creation of the mind map graphic.)

Once data has been transferred to mind mapping software, the SMEs reconvene to confirm tasks, to eliminate duplicate tasks, and to find similar tasks performed across multiple jobs. This is done using the mind map results projected on the wall. Further dialogue takes place, this time over the mind map instead of over the previous day's "sticky-note" concept map. This is the first time that SMEs see the collective results of their labeling and organization. Cross-links are not identified in this process. The facilitator assists the process flow, builds consensus among the participants, and assists the project manager in writing a summary report from the textual notes taken by the recorder; the Project Manager delivers the final report

2.2 CmapTools and the Navy

In 1997, the Naval Education and Training Center (NETC) began collaborating with the Institute for Human and Machine Cognition (IHMC) on a network-enabled prototype for knowledge modeling, browsing and sharing (Cañas et al., 2004, CmapTools, 2003), based on Dr. Joseph Novak's work with Concept Mapping and Learning Theory (Ausubel, Novak, et al, 1978, Novak & Gowin, 1984). In 1999, NETC chose representatives from the Naval Education and Training Professional Development and Technology Center (NETPDTC) to work with IHMC to find potential Navy applications for this prototype. By teaming with established Cognition Institute mapping experts from a meteorology concept mapping study and with Dr. Novak himself, the Navy/IHMC project team explored ways to leverage Navy training opportunities and performance support. As the IHMC software prototype evolved, and as more Navy users became familiar with the product, it became apparent that the top down hierarchy of a concept map, with linking words forming propositions, offered a clear way to organize training information.

2.3 JTA Workshop Using CmapTools

In the summer of 2002, NETPDTC was asked to facilitate a TFE commissioned JTA workshop for the Navy's Professional Mariner (PM) Ratings. The facilitators were expected to use the JTA "sticky notes" format of gathering and mapping SME data, but no mapping software was provided for the workshops. At this time, NETPDTC was collaborating with IHMC to see how CmapTools could be used to improve Navy training. Since the “triplet” design of a concept map proposition, containing object-verb-object, parallels the Job-Duty-Task reports being amassed under JTA, the PM workshop was an ideal way to show how CmapTools software could make the JTA process more efficient. The purpose of this workshop was to identify current jobs, duties, and tasks associated with three Navy Ratings: Signalmen (SM), Quartermasters (QM) and Boatswain’s Mate (BM). Since these Navy series have similar civilian jobs, key members of the civilian community were invited to identify civilian equivalent certification requirements.

2.3.1 Concept Mapping Jobs, Duties, and Tasks

IHMC staffers Dr. John Coffey and Ms Andrea Jost were provided as concept mapping and knowledge acquisition experts to assist the two facilitators at the June '02 PM Workshop. They introduced IHMC's CmapTools, using Cmaps to automate the brainstorming and mapping steps in the JTA process and to replace sticky notes with automated concept map projections. Coffey’s research (Coffey, 2004) describes in detail how group generated concept maps made the decision process more efficient. The groups worked diligently creating and refining the projected maps that led to other maps. Initial work was finished rapidly, and group members collaborated on additional mapping tasks that took advantage of the capabilities of CmapTools and the expertise available. Task duplication was easily identified. In addition, SMEs were quickly able to map the process of skill level advancement and certification in the Navy and to link those levels with the certification in equivalent civilian occupations. Using the software to collectively tap into the knowledge of civilian community certification experts who would not normally be gathered to brainstorm together made the outcome of the workshop more valuable. The adaptiveness of CmapTools to diverse graphical images greatly contributed to the success of the workshop.

Seeing the results of their dialogue develop before their eyes as the Cmap modelers placed their suggestions into the map helped the SMEs develop and group the tasks more efficiently than in the workshops using the sticky-note method. By taking advantage of what the SMEs already knew and by capturing that information quickly for all to see, the concept map modelers and the facilitators were able to stimulate group thinking. Collectively, SMEs were able to build on each other’s knowledge. SMEs saw the value in using concept mapping in a collaborative effort to identify some of the future occupational challenges they would face in their Ratings. Figure 3 is a concept map result of one of the future challenges brainstorming sessions.

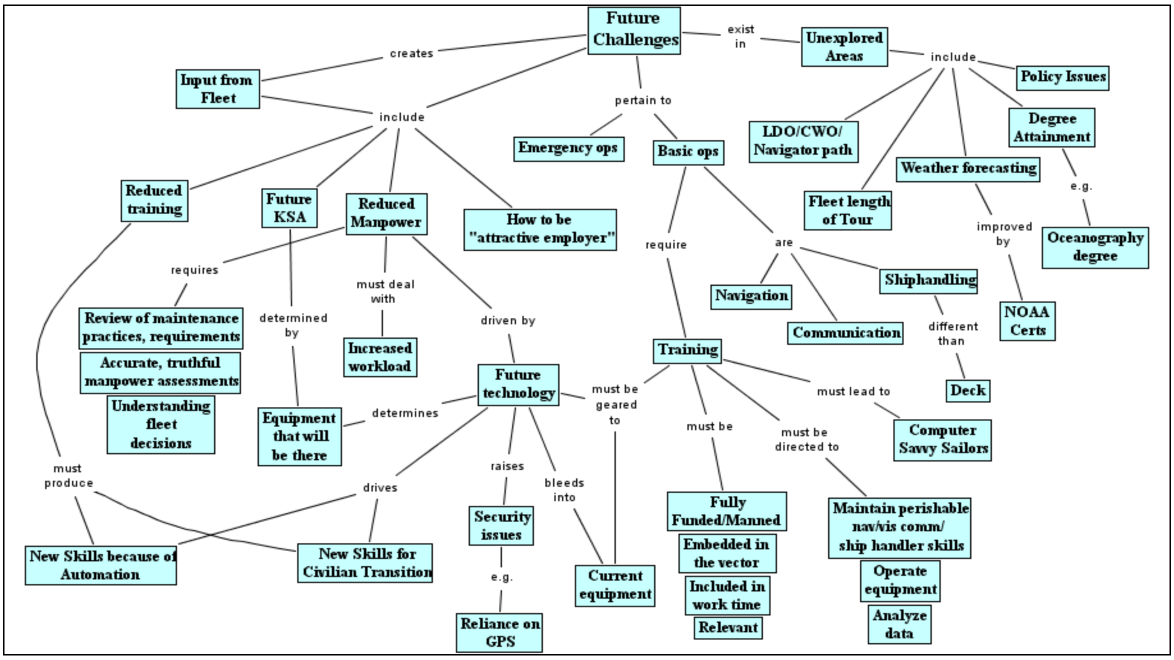

Figure 3: Future Challenges

At the end of the first day, the data had already been input and viewed by the participants as maps. The maps were printed for participants as a record of their decisions and as documents to review. In previous workshops, participants could not see the results of their collective efforts until the next day, after the recorder had input the data from the sticky-notes. Using CmapTools software to develop concept maps based on the concept mapping principles developed by Novak, the participants were able to come to consensus much faster than in JTA workshops using sticky notes. They were able to accomplish more in a shorter period of time, especially on the first day, and they were able to take away printed copies of the day's work to review and to prepare for the next day's session. The TFE Program Manager also reviewed results at the end of each day and commented on the speed in which the results were ready compared to previous workshops. Facilitators also remarked that this workshop was progressing faster than previous ones using sticky notes. They noted that the jobs, duties, and tasks, presented as concept maps at the end of the first day, would not have been compiled and presented as mind maps until the second day in the sticky note workshops. SMEs stated that using the CmapTools projections rather than sticky notes helped them work more efficiently. They liked being able to see the results immediately, rather than waiting for the data to be input and to see the results the next day. What was especially helpful in this exercise was the ability to make cross connections and show relationships not always so obvious in the day-to-day operations. Seeing each other's ideas captured collectively, SMEs were able to expand data as each contribution was recorded.

2.3.2 Mapping the Vector Information

In addition to making Novakian concept maps, CmapTools was easily adaptable to the flow of the discussion and did not limit the user to a specific structure. The skilled concept mapping modelers were able to capture certification data offered by civilian community experts and combine it with USN certification data to make a linear vector. Figure 4 is an example of a resulting certification vector graphic.

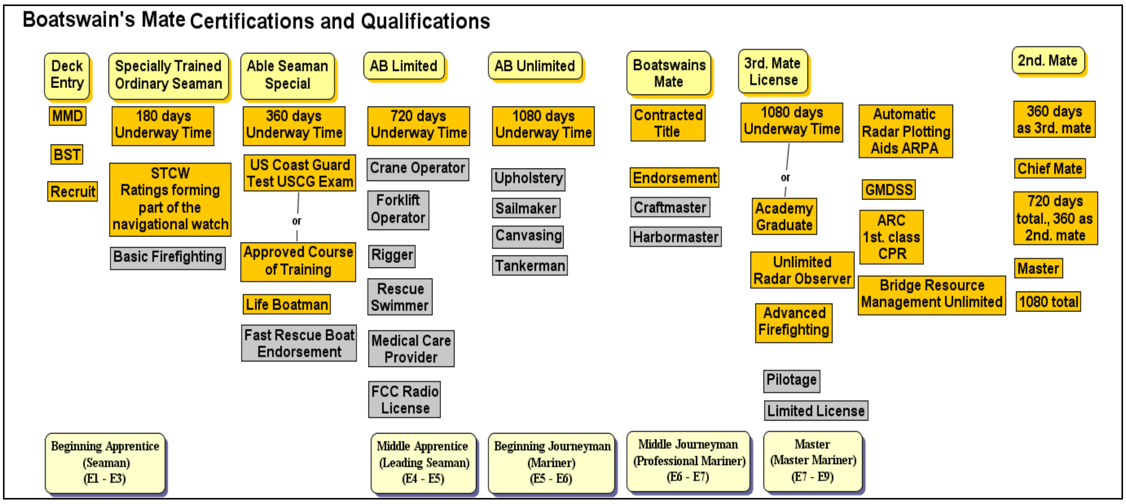

Figure 4: BM Certification Vector Information

By inserting certifications at appropriate points, the modelers depicted the type of information that would be available along one arm of the 5VM for BM and QM Ratings. Sailor and civilian experts could see the progression as it developed and were able to make instant comments and corrections that increased the accuracy of the graphic. With the benefit of adding resources to concept objects, modelers were able to attach links from civilian and military experts that could be used for further explanation. Civilian and military certifications were colored differently, so that variations and gaps were clearly apparent. SMEs stated that they appreciated being able to collaborate with the civilian community experts and see for the first time how their certifications matched or did not match civilian job certification. They remarked that the civilian expert data could not have been captured and merged with theirs so easily without CmapTools. The civilian experts were impressed at how quickly the information they offered could be organized and merged with the military data. Because of the CmapTools projections, they were even able to collaborate among themselves and better capitalize on the civilian knowledge available than in previous JTA workshops. The loosely termed "map" could be used by the Navy to identify where to align USN certifications more closely with the civilian community.

The certification vector data was compiled and organized so quickly using group brainstorming over the CmapTools software projections, that the group also had time to map out the professional development vectors for the PM Ratings. In the final version, the group was able to attach text files as resources describing what is required at each level along the vector. The work progressed so quickly at this point that the SMEs were also able to add resources that described each duty assigned to each job. Figure 5 shows the final result of a QM professional vector brainstorming session map.

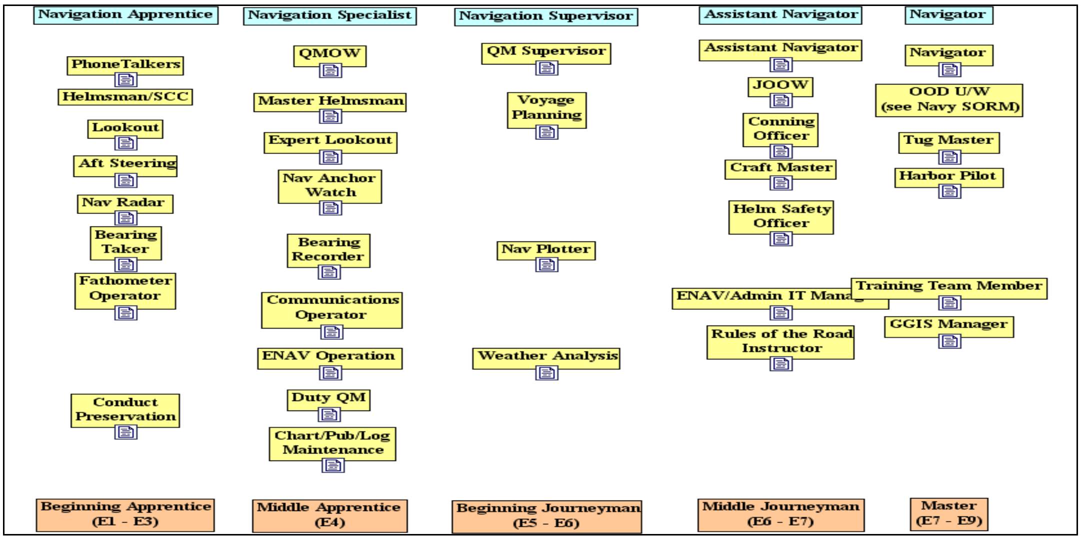

Figure 5: QM Professional Development Vector information

The concept maps and graphical representations of the workshop results were easily converted to jpeg format and were used as illustrations in the final report Word document and in the PowerPoint summary presented at the end of the workshop. CmapTools software was even used to show a graphical job progression (figure 6), where duties diversify as a sailor progresses, then merge again into common duties at the top level of the sailor's career. The program manager was so impressed with the versatility and efficiency CmapTools software that, in his out-brief to the executive manager, he specifically stated that using CmapTools software greatly improved the PM JTA workshop process. He also recommended that this software be considered for use in all future JTA workshops.

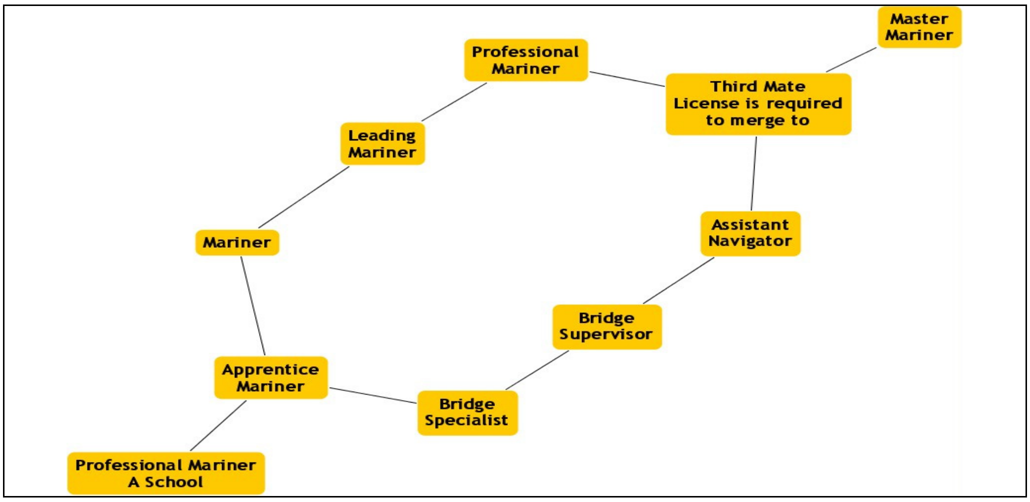

Figure 6: Job Progression

2.3.3 Evaluation

The use of Concept Mapping and CmapTools software helped not only to streamline the PM JTA effort but also to assure that participants had a clear understanding of the outcome. The PM concept maps really drove home the fact that concept mapping can reveal relationships not usually recognized in ordinary discussions and can show the big picture as well. Many concept maps were developed that contributed to the group processes and eventually led to final consensus maps. A total of 11 final concept maps and 7 object maps were produced and used in the final reports. Although other JTA workshops had included experts from the parallel civilian occupations, the expert knowledge had not been captured as effectively as it had using collective collaboration and CmapTools. The projection of the map graphic, and the use of experienced concept map modelers, gave the group a clear picture of the progress they were making and of the outcome at the end of each day. Usually participants waited for the written report to see final results. Sometimes the written report did not agree with the participants' perceptions of what was concluded.

Mapping can eliminate the pitfalls of linear, sentence-oriented note taking and can help to recall verbal images and ideas. Buzan has found that 90% of the words used in note taking are unnecessary. He has identified a few of the problems that occur when we attempt to get information from the linear note structure (Buzan, 1991): there are wasted words that do not assist in recall; there is wasted time searching for words needed to recall ideas; there are unrelated interruptions between related ideas and key words. Using mind mapping software can produce good JTA results. Building on existing knowledge and using a graphical representation in the form of a concept map with linking words (Novak, 1998) allows participants to visually enhance communication as well as build on existing knowledge. Although the links may be assumed to be understood in mind maps, the links are clearly stated in concept maps.

The advantages of using CmapTools software as an automated version of the JTA "sticky note" process were apparent from the onset. The facilitators observed that group dynamics began to surface much sooner than in earlier workshops. The SMEs were highly engaged as a cohesive group to produce the tasks, discuss them, group them, and to come to consensus much more quickly than waiting until the sticky notes could be grouped on the wall then copied into a software product. Using CmapTools software and expert modelers, the facilitators were able to distill the most useful information from the vast amount of knowledge and expertise present at the workshop. The anecdotal results of the PM JTA workshop show that it is more efficient and more effective to achieve group consensus using the concept mapping of CmapTools than with ordinary note taking, summarizing, and mind mapping later. This was not a controlled study, so the results are based on observation and comments:

JTA Using CmapTools	**JTA Using Sticky Notes**
Group focuses on projected map and stays on task; group dynamics form quickly.	Participants work individually on sticky notes, then in small groups; dynamics are slower to form.
Concept mapping can reveal cross relationships not easily identified.	Cross relationships are not identified or revealed.
Changes can be made quickly, gaining group consensus immediately.	Changes are not as easily made; group consensus is not obtained until the next day.
Group product (map) is visible to all as work progresses.	Group product (mind map) is not available until all data from sticky notes can be input.
Group determines construct of the concept map; group reviews map as it is built.	Recorder determines construct of the mind map based on the sticky notes; group must review and concur or suggest changes a day later.
Modelers can make graphical depictions in styles other than true concept maps; software can be used for sequences and stages required for the 5VM as well as flow charts.	Software used only allows construction of a structured mind map.
Results are easily provided for review; maps can be printed at end of each session, and group can suggest changes at next session.	Some results can be compiled and made available for review the next day; some results are not available until after the workshop concludes.
Facilitators distill information with the participants and during the meeting.	Facilitators distill information without the participants and outside of the meeting
Facilitators can quickly acquire expert knowledge from outsiders (i.e. civilian community, industry, etc.) and integrate/merge it with SME knowledge with SME/ expert consensus during mapping.	Facilitators gather outsider knowledge in a linear format and integrate/merge it with SME knowledge in isolation, after the workshop concludes.

Table 1: Using CmapTools versus Sticky Notes

3 Summary

JTA processes can benefit from the use of concept mapping (Trochim, Cook, & Setze, 1994) and CmapTools software. A concept-map oriented approach to grouping tasks in terms of major concepts (rather than simple lists of tasks in a table may potentially add to current job understanding and a more meaningful approach to training. Using CmapTools software to develop concept maps based on the concept mapping principles developed by Novak helps the participants to come to consensus faster than using the sticky note and mind mapping method; they are able to accomplish more in a shorter period of time. Job progression, Certification and Professional Development requirements can be depicted graphically, as well as concept maps of Jobs, Duties, and Tasks. Group dynamics are evident as the participants start thinking together to build on each other's knowledge; visual images are quickly completed by expert concept mapping modelers to keep group on task. Using the software to collectively tap into the knowledge of experts who would not normally be gathered to brainstorm together could make the outcome of the workshop more valuable. The usefulness of graphically flexible CmapTools software to depict maps and process flows outside of the actual concept map format suggests that this software has many applications. It can be used to facilitate many types of Knowledge acquisition, process flow and mapping meetings. A key factor in taking advantage of the group process flow is the use of expert modelers who are able to keep up with the diverse ideas being presented. Recording skills and software knowledge is important, but mapping and modeling ability is also necessary. The adaptiveness of CmapTools to different graphical representations can greatly contribute to the success of a JTA workshop.

4 Acknowledgements

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MAPPING KEY CONCEPTS IN CULTURAL ANTHROPOLOGY

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Abstract. In this paper we describe our experiences while exploring alternative approaches to explain social theory in an undergraduate course in Social and Cultural Anthropology. We started out with a keyword-mapping exercise. CmapTools was then used to introduce the idea of concept mapping. This approach was complemented by a Web/Wiki based Hyperglossary application to define keywords that were connected through hyperlinks. We reflect on the role of key concept mapping for the achievement of the specific learning goals of the course and on its usefulness in Cultural Anthropology in general.

1 Introduction

This project began with the simple question: How can we help students better learn social theory?

"Theory in Social and Cultural Anthropology" is a regularly taught undergraduate course at Stanford. The course reviews major figures and key thinkers in social theory. As an introductory course one of its pedagogical aims is to introduce students to the life as an academic. This means we like to engage them in scholarly debates, to help them understand the logic of argumentation and make them see theory as a fundamental toolkit for their work as anthropologists. A scholarly debate is an interactive process, where multiple viewpoints are considered and contested. However, it is very typical that initially students tend to look at the instructor as the authority to explain major theoretical concepts. It was one of our main objectives to engage students and make them participate in the debate as experts.

Inspired by Raymond Williams' notion of "keywords" (Williams 1976) we began with the idea that social theory can be thought of in relationship to key concepts that help to create social reality. Keywords help generate a sense of the historical context of key thinkers, their intellectual network, genealogies, and heritage. Key concepts become then critical elements of an academic's toolkit. Research in social theory happens through the continuous discussion of terms in a scholarly debate that includes multiple points of view. Along the lines of a notion of divergent thinking key concepts are contested based on different definitions, interpretations, and views on the readings. There is no absolute, true answer, but students are encouraged to think through a problem from multiple perspectives and evaluate the analytic framework using the key concepts in play. This is what marks the learning process.

We were drawn to the idea of concept mapping for two reasons: 1) The process of graphically mapping out and negotiating keywords in their relationships to each other seemed an intuitive alternative to a more traditional, merely textual approach, and 2) since we were envisioning the creation of concept maps as a collaborative endeavor, we felt that such a tool could be applied to facilitate a peer-to-peer discourse, thus de-emphasizing the instructor as expert.

2 The Course

The course offers an introduction to social theory through an engagement with three intimately related arenas: the social, the cultural, and the global -- distinguished here only for heuristic purposes. It is now common practice to establish a classical moment of social theorizing, a moment when Marx, Durkheim, and Weber are viewed as founding analysts of the modern social condition. Yet, it is useful to consider the context in which these figures emerged as important theorists. Indeed their invention as fathers is more recent than we may think. The course engages the ideas of these thinkers while situating them in wide-ranging debates that extend their thoughts in a number of ways. How does social theory intersect with contemporary issues? The answer can be approached two ways: (i) taking the theory and mapping it onto the issues as stake and (ii) analyzing the issues for implicit assumptions.

2.1 Learning Goals

Objective of the class is to make sure that students acquire a knowledge of social theorists that serves as a basis for their training as cultural and social anthropologists. Students need to understand the interaction between the idea of the social, cultural and the relation of subjects' location, gender, class, and ethnicity position. Of concern as well is how "social theory" can be applied for contemporary social issues. Integral is the role of the analyst in the making of theory.

In order to achieve this objective students engage the thoughts of social theorists critically and raise questions about method and underlying assumptions of an argument. This provides an opportunity for them to appreciate the strengths and limits of the arguments presented within the context of a certain theory.

Students are required to write a research paper that is the culmination of their preparation in how to design a research problem, how to find evidence and how to make an argument. An example is the analysis, reinterpretation and critique of a newspaper article, assuming a theorist's perspective. To that end the theory as well as the theorist as a historical figure must be put in a contemporary context. One way of doing this is through the elaboration of keywords and their definitions.

2.2 Challenges

This course is an undergraduate seminar for anthropology majors. Most students come in with little prior knowledge of theory in the social sciences and believe that the instructor will provide the "correct" answers to the questions. Oftentimes the content is difficult to grasp, and thoughts are not very accessible. It is not immediately obvious for students why they should bother reading the heavy works of old theorists. While the task of writing up definitions of keywords has always been part of the teaching in that class it also has been challenging for the students to see the relevance of that task and to make the connections to the bigger context and content of the course.

In keeping with the notion of education for empowerment our intention was to find alternative ways of approaching a theory laden course that would allow students to represent key concepts differently in a way that would motivate students to deal with the material actively and collaboratively.

3 Our Approach

3.1 Mapping keywords: the whiteboard

Our approach builds on an experience in a prior class we taught about Cultural Studies. As an introductory exercise we provided students with a list of keywords and the assignment to map those out on a whiteboard. This assignment was done collaboratively in groups of three and four. It was purposefully done at the beginning of the course under the assumption that students would not have much background on the keywords. We aimed to help them to approach the topic by generating questions, by provoking them to provide their reasoning behind the respective definitions and use the various map representations to generate a discussion around different views of the new research field.

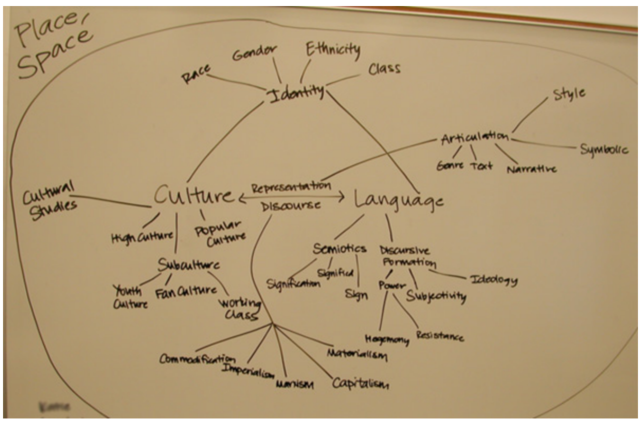

Figure 1: Student generated collaborative map of keywords on Culture

Fig. 1 provides one example of a map developed by one of the student groups that comes close to a concept map centered around two core terms, culture and language. Other maps involved the use of two whiteboards on top of each other to create a layered, quasi 3-dimensional representation or the introduction of images (tree) as metaphorical visualization.

3.2 *Defining keywords: the Collaborative Hyperglossary*

Based on this experience we parted initially from the idea of having students collaboratively edit and discuss different definitions of keywords. For that reason we started out searching for a Web based collaborative editing environment, which led to using a Wiki application (Twiki™ - A Web Based Collaboration Platform from http://twiki.org), very much alike Wikipedia (http://en.wikipedia.org/wiki/Main_Page), an online collaborative dictionary. The interface provides an easy way to publish simple webpages that can be interlinked, and the underlying philosophy of Wikis as an open environment allows anyone to edit and comment on any pages.

We adapted the tool to our specific needs, and designed it as a collaborative online hyperglossary. The "Hyper-Glossary of Cultural Terms" (Fig.2) allows users to simply edit and upload definitions and comments on key terms. Each key term is described on a different Web page. Multiple hyperlinks between can connect between the different pages, thus creating a hyperlinked network of related terms.

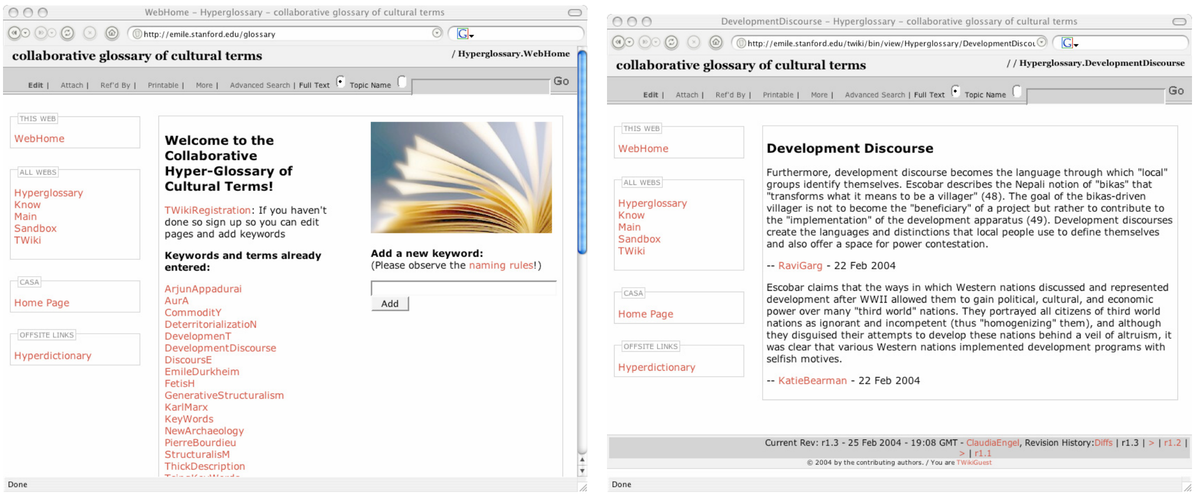

Figure 2: Collaborative Hyperglossary (front page and example of keyword definition)

The glossary can evolve and grow continuously over time around keywords and their contested definitions. We meant to have the students experience that there was not one correct definition and to motivate them to be responsible and create strategies on how to do their own research on the topics. A collective list of key terms that would allows students to appreciate ways certain terms is used to frame arguments and debates. We did not suggest any key concepts nor provide a list, but encouraged students to determine on their own which key concepts they would select based on their reading of the course material.

Because of time constraints and availability the hyperglossary could only be introduced later during the course. This tool was used mostly by students and less by the instructor. Even though we were concerned that there would be too much of a learning curve to understand the technology and rules of how to create pages and hyperlinks it was quickly adopted by students. Most of the activity in the hyperglossary happened outside the class.

In addition to the hyperglossary we considered a different application that would allow to map key concepts more visibly in a two-dimensional space and visualize relations graphically. Therefore we chose CmapTools (from IHMC CmapTools Knowledge Modeling Kit. http://cmap.ihmc.us/).

3.3 *Representing theory: Cmap*

Cmap was first introduced through the instructor and used by her to present a summary and a context for readings for particular seminar sessions. Mapped out were relationships between key thinkers, their historical context and influences, as well as connections to other readings (see Fig.3). The Cmap was uploaded to the IHMC server, where we set up a folder with restricted access. Hardcopies were printed and taken to class.

Students usually annotated those individually and took notes during the introduction of the readings and discussion.

After a few sessions students started adapting their way of working with the readings to a similar practice. Each session had designated discussants to prepare and guide the conversation of the assigned readings. Interestingly it was the idea of mapping out key concepts that was appealing, not the use of the CmapTools per se. Students typically provided an introduction and prepared a list of questions to get the conversation going. Later they started using the blackboard to write down key terms they themselves found relevant. The whole class would then contribute to the keywords and elaborate connections between the terms. The use of the CmapTools software in that whole process was only marginal.

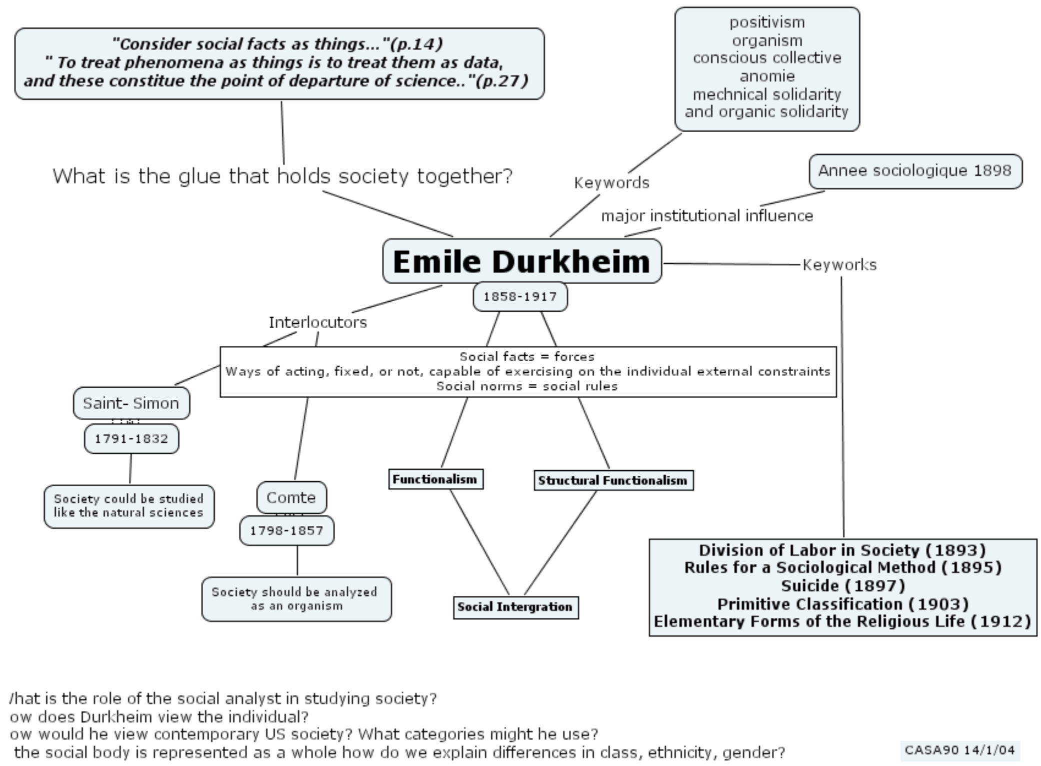

Figure 3: Concept Map: Introduction to readings from Emile Durkheim

4 Reflections

4.1 Comparison of the tools

Table 1 summarizes the differences that deemed relevant for our experience in the use of the two tools.

As the table shows, both tools are distinctly different in a number of characteristics. It was part of our experimental approach to try to use both instruments complementary and thus be able to take advantage of the strengths of both of them. While there are disadvantages to use two different systems, and while apparently the visual potential of Cmap was very appealing to the students and instructor we also felt that Cmap alone would not provide all the features we were looking for. For example, we wanted to promote interaction for the whole group outside of the classroom, and for some students installing the software did present a hurdle.

More elaborate versions of a combined approach of representing knowledge in an interconnected way, both visually and textually exist. One example is the Visual Thesaurus, where terms are connected in a 3-dimensional representation through different line types with different meanings, where proximity plays a role and a textual representation is included as well (http://www.visualthesaurus.com/online/index.html).

Cmap	Hyperglossary
• Graphical/visual • Potentially hierarchical structure • More focus on relationships • Links are visible lines • Client needs to be installed, PC only • Offline use possible • Collaboration happened face to face (in class)	• Textual/hypertextual • Non hierarchical structure • More focus on definitions • Links are (virtual) hyperlinks • Access through web browser, any OS • Can be accessed online only • Interaction with the tool remotely, outside class

Table 1: Comparison Cmap vs. Hyperglossary

4.2 Value of key concept mapping for the course

Reading and writing as typically individual activities and in-class discussion as potentially interactive are the traditional techniques used in cultural theory courses. With key concept mapping as a technique to approach the complexity of social theory we deliberately chose an approach radically different from conventional teaching practices in our department.

Cmap allowed for a genuinely different way of re-presenting and interacting with the textual material, while the Hyperglossary, even though built around the notion of keywords and potentially more collaborative, still might come closer to a conventional approach of writing. Inspired by the instructor using Cmap representations for her introductory comments, key concept mapping was picked up quickly by the students as an appealing alternative that highly motivated the group to interact with the assigned texts.

We also believe that the technique of starting out with a collection of keywords in a more informal way, almost similar to a brainstorming session, helped support certain leaning styles and most likely include more students in the class activities. We observed two very silent students who were coaxed out of silence by the technique. Maybe keyword mapping created a less formal and threatening atmosphere. Students could just throw out ideas - "I think X is an interesting word" or "The author uses the expression X and I don't know what it means", which then would become subject of the group debate.

In addition, and somewhat independent from the actual tool, we think that the collaborative aspect had quite an impact on students' perception of the class. The key concept mapping activities turned into an ongoing generative process. All participants were building something together with the potential to even re-use the material in subsequent courses.

Taking all this together and comparing it with earlier versions of the class this one allowed us to watch students transform from passive consumers to active participants in the achievement of their educational goals. In various conversations following the class students stated that they now see keyword mapping as a useful tool to help them approach certain theoretical domains and approach difficult reading material. Other instructors at the department became interested and Cmap was subsequently been used in a graduate Archaeology class on materiality.

4.3 Use of concept maps for understanding cultural anthropology

Concept mapping originated from the natural sciences (Novak 1998) and has been used exhaustively in planning, engineering, and assessment. Fewer applications from the social sciences are known, for example psychology (Jacobs-Lawson and Hershey 2002) or sociology (Trepagnier 2002). However, concept mapping can be of high potential value for theoretical domains where relations between concepts are often abstract and there can potentially be multiple connections (Trepagnier 2002, p.108). Specifically for the domain of cultural anthropology Raymond Williams' idea about keywords, resonates quite well with the notion of "mapping" of key concepts. He was trained as a literary scholar.

In fact, an important component of our approach is the relationship between concepts and words. Murphy (2002) in a recent comprehensive review of the research around concepts dedicates an entire chapter to "Word meaning" where he tries to argue for a specific relation between the process of making meaning of words in the context of concepts. For him "Words gain their significance by being connected to concepts" (Murphy 2002, p. 385). This, we believe, comes close to our perception of keywords and how we try to have students make meaning at the intersection of linguistics, discourse, and concepts - concepts understood as a collective term that brings together a number of ideas of a new field, still largely unknown to them.

Parting from the notion of "good scholarship" we may ask what it involves. Oftentimes, making an argument is important piece of it, something we are not sure key concept mapping alone can provide. Collaborative tools for computer-supported visualization of arguments (Kirschner et al 2003) might be an alternative to consider.

While generating a list of key concepts is relatively easy, a more difficult task during concept map construction is to find the "linking phrase" that appropriately expresses the relationship between two concepts to form a meaningful proposition. Concept maps are graphs that are comprised of concepts (defined by Novak 1998 as perceived regularities in objects and events). Social research in the 20th century can be broken down into several categories that are interrelated, contemporary, and that influence each other, like "kinship" networks, genealogies, schools, key concepts, and key players. Concepts and debates in social theory might be more controversial and complex than a concept map may convey. While under certain conditions it may be useful to simplify, on other occasions it may be detrimental, because too many implicit assumptions have to be made which can distort the representation.

Again, we ask: what does that mean for social theory? In addition to having possible multiple ways of mapping, oftentimes relations between key terms have meanings like 'context', 'situated', 'influenced by', 'awareness', all of those relatively unspecific connections, and it is not clear if it is it always possible to qualify connections. Is it useful to 'force' students to think about qualifying the connections between concepts? Here a different tool like the hyperglossary may have its advantages as connections don't have to be specified.

While it is clear that the concept maps produced in our class do not necessarily involve a hierarchical structure our approach is coherent with the underlying learning theory that learning takes place by the assimilation of new concepts and propositions into existing concept propositional frameworks held by the learner, and thus promotes meaningful learning (Ausubel 1963). However, for reasons of consistency it might be more appropriate to apply the term "topic maps" rather than concept maps.

The project presented here was meant to be an experimental pilot study to explore tools and innovative approaches that would allow us to apply the notion of keywords and key concepts and work with theoretical texts and contents in a non-conventional way. We don't have any direct evidence about how our intervention influenced the learning process other than seeing students motivated, more engaged and seeing them use the technique not only in other classes, but also for their own research projects. As usual in these cases, we have generated more questions than answers. However, we are intrigued by their potential for alternative approaches to academic scholarship.

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I KNOW WHAT YOU'RE THINKING: ELICITING MENTAL MODELS ABOUT FAMILIAR TEAMMATES

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Abstract. Research involving team mental models in the past has often focused on cross training fundamentals (correctness to a procedure) for the sharedness shown between teammates. However, evidence has shown that this may not be the best measure to distinguish a proficient team from a non-proficient team. Instead some believe that more emphasis should be placed on other cognitive factors being more closely related correctness to a teammates' schema. This paper attempts to tackle this task through the use of concept mapping and simulated tasks that require team efficiency. It is theorized that teams exhibiting the highest levels of both correct mental models toward and expert model (task correctness) and correct mental models toward teammates' mental models (familiarity) will perform at greater levels than those teams that are lacking in one or more of these areas.

1 Introduction

"I am convinced modeling and simulation technologies available today will enable us to significantly change the way we train in the future. We are at a crossroads where simulator technology today will be critical in the success of our effective use of follow-on weapon systems… We need to take a hard look at how this technology will change our training philosophy as well as how we develop future weapon systems." (Fogleman, 1996, p.1)

While certainly applicable in a variety of domains, the research theories being proposed here have a distinct practical relationship with crew coordination in aviation teams and in creating successful teams in military operations. In addressing recruits at Fort Jackson, Defense Secretary Bill Cohen shared his feelings on teamwork in the military. "Our military is the muscle behind America's will, and it is teamwork that makes that muscle strong…trust and teamwork are the only real guarantees that you can complete the mission." His sentiments echo across the services and surely into the domain of aircrew coordination. The need for trust and teamwork are evident for continued advances in safety and security.

This need extends beyond our borders, as well. As the need for policing actions on foreign soil increases, American servicemen are being asked to interact with multi-national teams of military "police" in order to keep the peace in many troubled countries.

Not only are our servicemen and women expected to interact with members of their own squad, but also with members of other groups, even other services and nations. Additionally, military units are sometimes being required to interact with a team which is not physically present and with people they may have never met before. According to Montoya-Weiss and her colleagues (2001), though there is an inherent value in being able to bring people who are not in the same geographic location together, it is also accompanied by its own unique problems. One of the most prominent is in poor coordination between team members (Wittenbaum, et al., 1998). This becomes even more important when one considers the fact that most group coordination occurs implicitly (Gersick, 1988).

In special operations combat teams, the need to have both explicit and implicit coordination is absolutely essential. If any differences exist between team members, there is generally not enough time to work out these differences. Members of those teams, therefore, plan very carefully, trying to address any and all possible problems. They realize, however, that no amount of planning will cover all scenarios. According to the Doctrine of Joint Special Operations "detailed mission planning, based on specific detailed, comprehensive, and accurate tactical intelligence is vital to successful mission execution and also to the very survival of the operational element"(DOD, 1996). So, these teams recognize the value of explicit pre-task planning. Additionally, team leaders are told that the objective of the planning process "is to develop a comprehensive plan that provides for flexible execution. S(pecial)O(perations) force commanders cannot tie themselves to a rigid plan. They must anticipate the unexpected and remain flexible enough to modify their plans, as required, to achieve their higher commander's intent" (DOD, 1996). This coincides very well with the concept of in-process tacit coordination, which is detailed by Wittenbaum and her colleagues (1998). Gersick and Hackman (1990) would also seem to agree, since their finding that groups who coordinated implicitly freed up more time for tasks to be performed, and time is of the essence in Special Operations missions, requiring precise actions at key moments.

The question that is really at hand here is, what factors contribute [most] to mental models being shared between team members, in an extremely efficient manner? Synthetic task environment systems should enable more controlled investigations while capturing performance phenomena in complex, multi-operator, expert-based operational performance (Driskell & Salas, 1992).

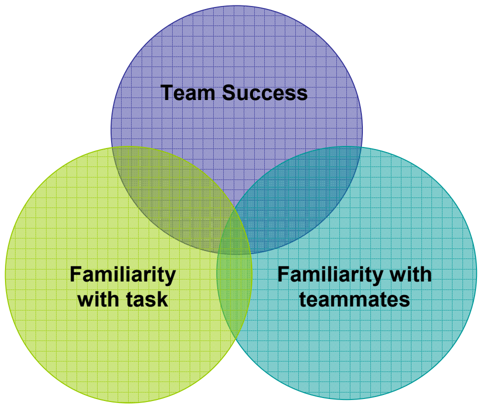
In addition to allowing its officers and men to play certain military-related commercial computer games on base computers (DMSO, 1997), the Marines have also been busy creating some training games of their own. Using a version of the commercial game DOOM adapted with the help of Lt. Scott Barnett, Marine fire teams have been training at computer labs in Virginia, Georgia, and North Carolina learning battlefield tactics and decision-making. “It’s funny, because at the end of the day I had to kick my Marines out of there and send them home,” Barnett says. “The Marines know they’re learning, but they’re also having fun. I think that’s critically important to get them to want to learn” (Prensky, 2001, p. 311). In the Marine version of the game, four member “fire teams” are networked together and play at four individual computer stations. Their goal is to coordinate their movements and eliminate an enemy bunker. The communication that occurs is verbal, as each team member can shout to their comrades. However, the most effective teams have less but more direct communication, a sign that their familiarity with one another has lead them to less need for explicit communication. Instead these soldiers anticipate teammates’ actions and coordinate their actions accordingly.

The idea of team performance being linked to shared mental models among teammates has been a topic of research that has gained substantial popularity over the past decade. Cooke, et al (2000) state that, “the growing complexity of tasks frequently surpasses the cognitive capabilities of individuals and thus necessitates the team approach”(p. 151). This statement is becoming increasingly true in many different team environments in today’s world, from professional sports to complicated military action. The standard knowledge in this line of research is that the teams with the ‘most shared’ mental models (or knowledge, knowledge structures, cognition, etc.) will be the teams that perform at the highest levels. Cannon-Bowers & Salas (2000) also reported that team members could actually have several different models depending on the topic area, such as an equipment model and a procedure model. It is believed that these shared mental models are what give teammates the ability to coordinate efforts when traditional methods of communication are not an option. The most commonly used example of this type of effort is the ‘no-look’ pass performed between basketball teammates. This task requires that teammates not only anticipate a pass but know when and where to anticipate either their teammate being or the pass coming from. Even in this simple example a complex interaction of teammates and their knowledge of both their duties and the tendencies of their teammates are required. For more complex and increasingly technological tasks this interaction only becomes that much more complicated.

The task for researchers came to be how to measure these mental models in a way that comparisons could be made to other teammates and then to other teams. While many options exist, including repertory grids, verbal protocols, and card sorting, concept mapping (Marks et al., 2002) is the knowledge elicitation technique that will be focused on here. First it is important to note that the recent research has use *text-based* concept mapping techniques. These techniques employ the use of cards used as conceptual terms that are then linked together in some fashion that is meant to be a physical representation of the participants’ mental models of a given topic or subject area. Some of the believed advantages of concept mapping over other elicitation methods, such as card sorting include the ability to capture procedural and strategic knowledge as apposed to primarily declarative knowledge. This allows researchers to examine the processes that participants are using within their mental models. In addition to these advantages, the concept mapping techniques employed in this study will provide additional information for both participants and researchers; however this issue will be revisited later in the paper. First, it is important to operationalize our definitions of teams and of mental models (knowledge structures, cognition, etc.). In 1992, Salas, Dickinson, Converse, and Tannenbaum defined a team as “a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform and who have a limited life span of membership” (pp. 126-127). To this definition one adjustment is to be made in that a team can consist of two or more people *or groups of people* (i.e. teams of teams).

As can be imagined, the term mental model, which is a concept that has many names, also has many definitions. Harper et al (in press) defines the construct of structural knowledge (another term for mental model) as, “an internal representation and organization of information utilized by an individual” (p. 2). This internal representation is what is then brought out through knowledge elicitations such as concept mapping. The part of this definition that is most interesting is “information utilized”. This statement makes no reference as to the “correctness” of this information or even the nature of its source. This is the grounds from which this idea to utilize concept mapping has advanced. Mental models, when elicited through concept mapping can be evaluated for correctness against an expert model, as well as for sharedness with other concept map elicitations. This quality allows for two distinctly different methods for which to evaluate team members' shared mental models, as they are correct with an expert model and as they are accurate regardless of correctness to a teammates mental model (i.e. sharedness). The premise behind this analysis is that teammates who have become more familiar with one another will be able to recognize errors in their teammates' mental models and thus be able to predict and compensate for these errors allowing for no significant drop in performance. This knowledge however will require more than just the standard of knowing one's teammates' tasks (cross training) but also knowing one's teammates' tendencies (familiarity).

Rentsch (in press) said, "Much of the literature on cognition in teams to date has neglected the idea that team effectiveness may be a function of not only the overlap of team members' cognitions, but also a function of other forms of cognitive similarity, such as teammates' awareness of their teammates' schemas." (p. 22). With this in mind, it is important to determine what factors are most important in the make up of effective team composition. Teams performance in this case could be compared on a simulation task as well as through concept mapping (that will include pictorial stimuli, a modality not previously explored in this research but proven to be significant in the work of Evans, Hoeft, Jentsch, Bowers, & Camizzi (2003)) versus both experts and their teammates. It is hypothesized that the teams showing the greatest amount of overlap with *both* the expert maps (correctness) and their teammates' maps (sharedness/familiarity) will have the highest levels of performance on the simulation task. Additionally, of the teams that either score high versus the expert *or* high versus their teammates on the concept mapping task, the group scoring high against their teammates will perform at a higher level in the simulation than those that only score high versus the expert map. This will provide support favoring the idea that familiarity of team members is a more important factor in team effectiveness than is team knowledge of the task.



2 Methodology

2.1 Apparatus

The data revealing how well teammates know one another could be collected using the TPL-KATS concept mapping program (see Figure 1), IHMC's CmapTools software, or one of many other concept mapping packages. These software packages have been found to be comparable to traditional manual concept mapping methods by Harper et al. (2002). Using TPL-KATS software, participants would execute the concept mapping program in much the same way as the solitaire game that is found on most PCs. Concepts can be 'dragged' by clicking on them and pulling them across the screen to the desired location. This software allows for the addition of multimedia (pictorial) stimuli to be attached to the concept terms (see Figure 2). For more information on the software please see Hoeft, et al. (2002).

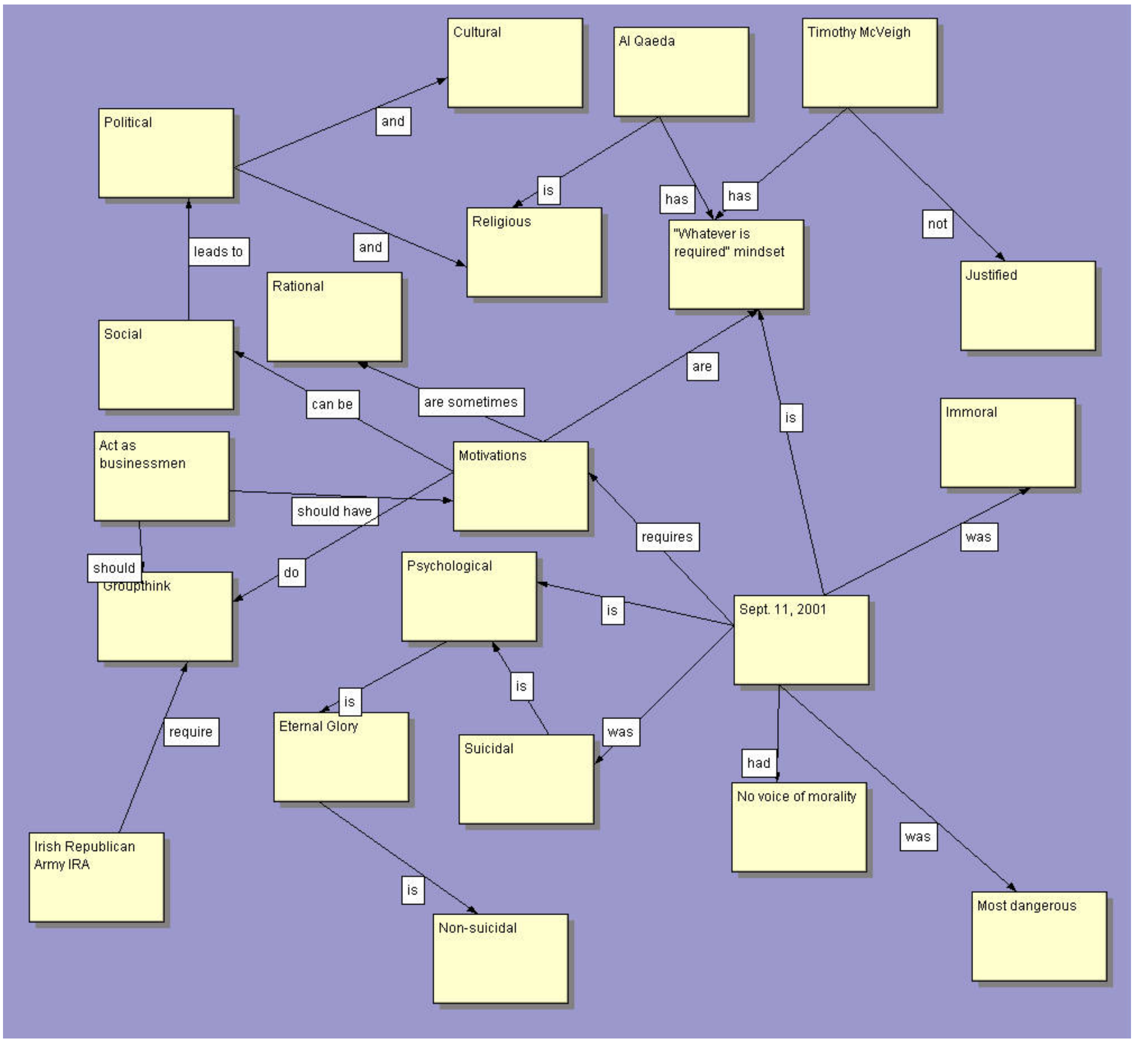


Figure 1. Example of completed concept map using TPL-KATS

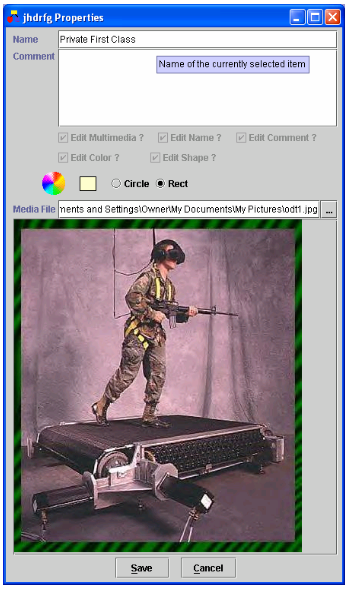


Figure 2. Example of multimedia stimuli using TPL-KATS

2.2 Scoring

Often an area of debate, the relationships would be rated using a simple scoring method. A score of "1" means the concepts had a direct connection, via an arrow and proposition term and a score of "0" means the concepts did not have a direct connection, via an arrow and a proposition term. This means of 'scoring' a concept map has recently been found to have no significant difference from more complicated and time intensive methods (Harper et al, manuscript).

3 Results

Using this data coupled with the other biographical data there will then be an opportunity for a regression analysis to be performed. The data yielded from such an analysis could provide valuable information as to what factors can help to most accurately predict the make up of a successful teams' members.

4 Application

If the hypotheses in these theories are supported, new light would be shed on the world of shared mental models. Data would recommend that rather than devote increasing amounts of time to cross training (though cross training is still important) that instead we focus more on training teams to be familiar with their members. This means that one should know his teammates attitudes, abilities, tendencies, fears, etc. In addition, this data would provide another step in a more expansive form of shared mental models, which is shared mental models of teams of teams. Advanced research in this area could provide for increased proficiency in the global arena of military operations affording commanders the knowledge of not only what there colleagues and counter parts should be doing procedurally both also what they will most likely be doing strategically.

As well, if regression analysis shows significant results, this research could play a significant role in the formation of new selection criteria with which teams will be constructed. A new base model could be formulated from this data, providing for a new set of characteristics that contribute to the identification of a 'good' team member.

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Concept Maps: Theory, Methodology, Technology
Proc. of the First Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

THE VALUE OF CONCEPT MAPS FOR KNOWLEDGE MANAGEMENT IN THE BANKING AND INSURANCE INDUSTRY: A GERMAN CASE STUDY

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Abstract Major industrial countries gradually developed from industrialised economies to information- and knowledge-based economies, where people became the most valuable asset to companies due to their abilities and valuable tacit knowledge. Unfortunately tacit knowledge is contained in people's minds, is difficult to access and therefore needs to be captured so it can be shared amongst employees. Concept maps are such a tool that can gather knowledge from individuals and groups, facilitate the knowledge creation process, function as a discussion and communication tool, and assist in the distribution of knowledge and learning processes within an organisation.
In order to evaluate the value of concept map technology, to gain detailed information about the company's current knowledge management system, the technical infrastructure, and to acquire insight about the possibilities and problems of concept maps, a survey was conducted at a banking and insurance company to determine the employees' degree of satisfaction with the current knowledge management system; their familiarity with concept map technology; and their willingness to work with concept maps. The results indicated that the employees are not fully satisfied with the current knowledge management system because of its unstructured character. The company's knowledge workers require, and therefore search for a wide range of knowledge currently spread over a number of different sources. Documents and other sources of knowledge are not sufficiently linked, and do not contain key words or descriptions for complex searches. This influences the acquisition of knowledge and search results negatively. A very positive reaction was thus expressed by employees concerning new concept map technology. Concept maps were familiar to a large portion of the participants, and an even higher percentage said they would use this new technology for knowledge acquisition and distribution.
Interviews with several employees and senior managers from the company were also conducted. Insight was gained by applying concept mapping technology to different fields in the company.

1 Introduction

Knowledge management in the business sector began in the early 1990's when organisations realised that harnessing a company's knowledge and collective expertise, and distributing it to the right people at the right time, is essential to every organisation and can give the organisation a competitive advantage over competitors if the knowledge assets are utilised more effectively and wisely (Demarest, 1997; Drucker, 1999a, 1999b; Grulke, 2000; Hardijzer, 2000; Birkenshaw, 2001; World Bank, 2002; Riches, Kemp, Wolf, Pudlatz and Le Moult, 2003). Managing and leveraging knowledge thus has to be at the core of any attempt to improve an organisation's performance (Barquin, 2001). Therefore the last few years have been characterised by an ever increasing need for tools and applications that capture this knowledge effectively, promote efficient distribution, enhance intuitive usage and provide the ability to link concepts of knowledge to other (multi-media) sources.

Companies are therefore investing large amounts of money in the development of knowledge management systems of which intranets, document management systems and data warehouses are the most popular technologies (McCune, 1999). When these systems are applied correctly by following a knowledge-centric approach with the necessary emphasis on information technology, as well as creating an environment conducive to knowledge creation and sharing, companies often experience a large increase in their return on investment (Skyrme & Amidon, 1997; Wiig, 1999).

One of the tools being used for knowledge management is concept maps, which entail a graphical method of acquiring and representing tacit knowledge. Although the graphical display of tacit knowledge has been in use for centuries as a method of expressing individual thinking, concept maps provide a functionality, which enables the user to share his or her knowledge, to collaborate with others, and to show the logical connection between concepts. Furthermore, concepts can be re-used, and information in the form of voice, documents, or movie clips can be added. Concept maps are therefore a very useful cognitive tool in acquiring knowledge and making it available to others in the science and business environment. Concept mapping is not the only mapping technology available, but unlike concept maps with their hypertext function and hierarchical structure (Novak, 2002), other mapping technologies, like the Petri-Network, often face the problem that as complexity increases, clarity decreases. This phenomenon is sometimes referred to as "lost in hyperspace" (Mandl & Fischer, 2000).

The value of concept maps lie in the ability to formalise and display tacit knowledge, as well as to transfer it with the help of pictures, movie clips, voice, text, structure or other forms of description to explicit knowledge. There are currently three major fields where concept mapping is used, namely as a teach-and-learn strategy tool, a cooperation process application, and as a tool for knowledge gathering, diagnosis, and modelling (Mandl & Fischer, 2000).

2 Objective and scope of the research

2.1 Objective

Since the use of concept mapping tools in knowledge management is relatively new, the objective of the research was to investigate the above-mentioned value of concept maps in the management of knowledge in the banking and insurance industry, because banking is an information- and knowledge-based business.

2.2 A German case study

To research the value of concept mapping in the banking and insurance industry it was decided to follow the case study approach. The head office of a company located in the northern part of Germany that provides banking and insurance services to its customers was selected. The company is highly information and knowledge based, and must meet the requirements of 200 head office employees. The customer base of the company is almost 255 000 customers and the balance sheet amounts to more than 5.6 billion Euros.

Almost all 200 employees have access to the local network and work with Lotus Notes applications, which are directly connected to an in-house Oracle database. Lotus Notes is used for the following tasks: messaging; news distribution via "info-tiles", actualised by each department; applications for workflow and organisation; providing forms; platform for programmed problem solutions; InDoc job description and work instructions; and user service for technical problems.

Lotus Notes was chosen by the company because it is an integrated groupware package; is fast enough for all required applications; and provides the security facilities required in a banking environment. It creates a group communication environment that allows the user to access and share information. Beyond standard email, database, and bulletin board features, Lotus Notes provides text editing, and facilities for document and workflow management. It has a graphical interface and uses client/server architecture that renders itself very suitable for implementation in a company wide intranet.

2.3 Knowledge management within the company

Experts' knowledge and best practises are presently exchanged through the news service ("info tiles"), the Lotus Notes bulletin board, meetings, seminars, or informally. All employees have access to the "info tiles", sorted into topics by each department. The departments are responsible for their own sections and have to update important topics. All employees are able to publish an article within the "tile" of their department, and depending on the topic, also in some of the other departments. Additionally, news messages are sent to inform employees about important issues. External knowledge is acquired through a service that provides economic and business news, analysts' reports, industry changes, and regulative changes issued by government.

In addition to the technological support of knowledge management, employees receive training with regard to the exchange of knowledge, especially for the dissemination of best practises. Regular seminars are not only provided to facilitate knowledge creation within the company, but also to provide details and information about new company products. The company concentrates very much on product training and best practice seminars to facilitate knowledge creation and its distribution. Therefore, a great deal of effort is put in the provision of regular training and seminars to all employees.

Similar to other companies, knowledge is facilitated in project teams, through investment projects, company evaluations, and in product innovation team sessions. Teams usually comprise members from different backgrounds and with a variety of skills. These may include a business analyst, a professional investor, different customer consultants (for private and organisational customers), cashiers, and client advisors. Cashiers and client advisors work in different positions and rotate jobs regularly. They therefore have good customer knowledge, important for decision-making in most projects.

For technical problems, the company has implemented a sophisticated document management system with direct enquiry and archiving features. With the help of document descriptions and key words, searches and solution entries can be undertaken by all employees.

3 Methodology

After interviews with management and key employees within the company to gain insight into the organisational structure, different kinds of work tasks, key performance areas, and present electronic and non-electronic sources of knowledge, a questionnaire was developed consisting of three categories:

- Demographic details;
- An evaluation of the company's current knowledge management system - its use, different possibilities to manage knowledge, and how the system fulfils the employees' needs; and
- An evaluation of employees' knowledge of concept maps, their experiences and the usability of concept maps in the company.

Using a staff list as sampling frame of the population of 200 employees, 80 employees were randomly selected throughout all levels of the organisation, which included employees from the banking, real estate, and insurance sectors of the company. From the 80 distributed questionnaires, 25 responses were received, which represents a response rate of 31.25%.

A second phase of the empirical study involved the creation of various concept maps with company experts to evaluate the value and possible applications of concept maps in the company.

4 Results

4.1 Demographics

The demographic responses indicated that the majority of the responses (28%) came from private customer consultants, followed by 16% from general consultants. Employees of the insurance department and corporate customer consultants each amounted to 12% of all responses. The rest of the answers were spread over the various other departments and is a good reflection of the real distribution of all employees.

The distribution of the age and length of employment of respondents are respectively illustrated in Figures 1 and 2 below.

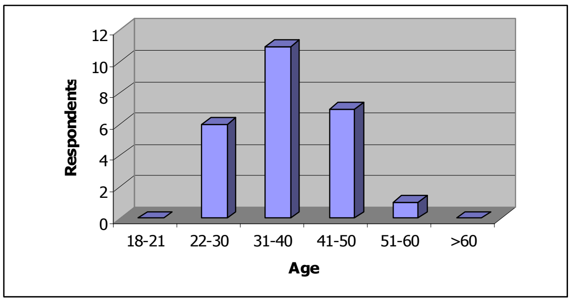

Figure 1: Age distribution of employees

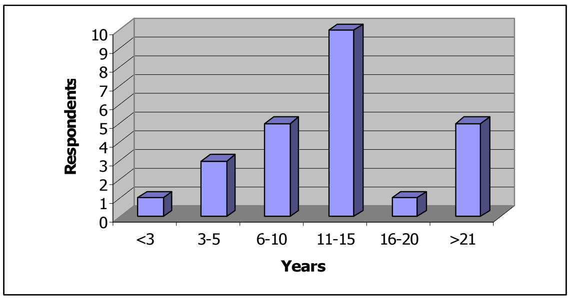

Figure 2: Length of employment

From Figure 1 it is evident that the majority of respondents (44%) were between 31 and 40 years old, with the lowest number between the ages of 51 and 60 (4%). The rest were evenly distributed between 22 and 30 years (24%) and 41 and 50 years (28%). Figure 2 shows that the length of employment peaks at category 11 to 15 years (40%), followed by 6 to 10 years and more than 21 years of employment (both 20%). With only 16% of employees working less than 5 years for the company, it is apparent that most employees have been working for the company for a considerable time.

4.2 Current knowledge management

Various knowledge resources are presently being used by employees, as is illustrated in Table 1.

Resource	Resources used		Preferred resource	
	Number	Percentage	Number	Percentage
Intranet	22	21.0%	15	30.6%
Colleagues	20	19.0%	13	26.5%
Internet	18	17.1%	6	12.2%
E-mail	15	14.3%	6	12.2%
Internal database	9	8.6%	4	8.2%
Training/seminar	4	3.8%	1	2.0%
S-Finanzberatung	4	3.8%	0	0.0%
Internal brochures	3	2.9%	1	2.0%
Job description	2	1.9%	1	2.0%
Magazines/literature	2	1.9%	1	2.0%
Other (all < 1% each)	6	5.7%	1	2.0%

Table 1: Information and knowledge sources

From Table 1 it is clear that the Intranet, especially the Lotus Notes "info-tiles" (21%), direct communication with colleagues, managers, and experts (19%), Internet searches and investigation (17.1%) and e-mail (14.3%) are the most important sources of knowledge. Although many sources of knowledge are being used, knowledge provided in the Lotus Notes environment (30.6%) and direct communication to colleagues (26.5%) are the preferred sources and are perceived to be of a higher quality than the others.

When the level of fulfilment of users' needs by the current knowledge management system was measured, almost 48% of all respondents indicated that they feel indifferent, 36% were satisfied, and 8% very satisfied, with only 8% unsatisfied or very unsatisfied with the quality of their searches and requests on the current system. The results are displayed in Figure 3 below.

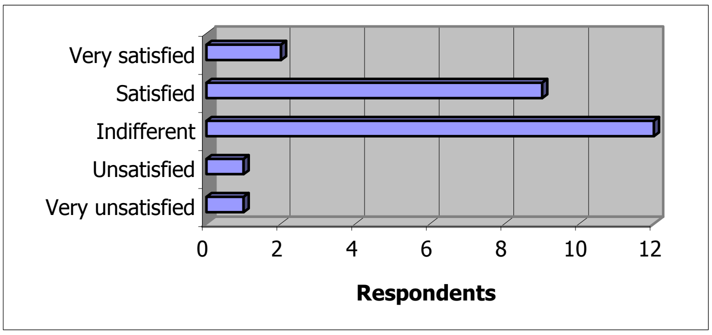

Figure 3: Employees' evaluation of the current knowledge management system

Respondents were asked to motivate their evaluation of the current knowledge management system (Figure 3). Respondents mentioned that the current system lacks an attractive layout, which prevents employees from using it. Other major issues concern the current quality of linkages between documents, key words, and short descriptions used to identify the correct or desired document. This functionality is currently not working sufficiently, and decreases the quality of search outcomes. It also leads to an additional information overflow and reduces the use of the system. One respondent mentioned that direct contact with colleagues makes more sense than a computer based knowledge management system. It is more praxis orientated, connects knowledge to real life cases, and offers an important social component (communication and confirmation). An additional concern was the speed of the current knowledge management systems, which is too slow for complex internal searches. This has led employees to use other knowledge sources, like the internet to acquire information and knowledge. However, the comment that probably best explains the distribution of the respondents in Figure 3 is the comment that the company's information system is sufficient for all basic tasks but fulfils no higher needs.

4.3 Concept maps

Eleven respondents (44%) indicated that they have heard of or have previously worked with concept maps. Mapping technology, for instance, was used by members of the human resources department, employees in project management, and staff councils for training/seminar planning, brainstorming, development of new products, presentations, discussion platforms, taking notes in presentations, projects (especially for recurring structures – re-use of possible guidelines and framework), and personal knowledge archives.

When respondents were asked if they would use concept maps as a tool to make their knowledge available to others (assuming the implementation of such a system on the company's intranet), 60% reacted positively and indicated that that such an application would be useful to the company. A total of 28% percent of all respondents were not sure if they would use concept maps to make their knowledge available, and 8 percent indicated that they are already using this technique. Only one participant said that she/he would not use such an application (See Figure 4 below).

Respondents were next asked if they would use concept maps for knowledge acquisition purposes such as the learning of problem solving processes, expert knowledge, and gaining knowledge from other professionals. A total of 68% of all respondents said that they would use the concept map technique to benefit from other people's knowledge. Only 28% were not sure if it would be the right tool for such a purpose. The same respondent, who would not use concept maps for knowledge sharing, would not use this technique for knowledge acquisition. Due to the unavailability of concept maps, the two employees, who already use concept maps, obviously do not use concepts maps for knowledge acquisition. The results are summarised in Figure 4 and are probably predicated on their previous experiences or lack of experience.

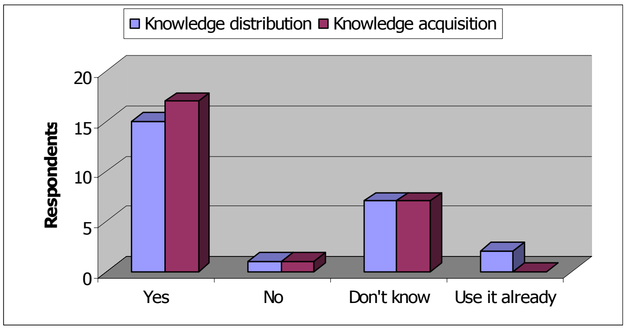

Figure 4: Willingness to use concept maps

When respondents were asked to evaluate their experience with regard to concept maps, a few respondents stated that concept maps are an excellent tool for the representation of knowledge. One respondent was more specific and remarked that concept mapping is an excellent knowledge management tool, but is only suitable for introductory representation of a topic, or to obtain an overview of a subject. If a map is extended with details and special knowledge, the clarity of the map is lost. Other respondents explained that their experience with this technique as a simple presentation method has been very positive. Concept maps can be applied as a tool for different problem solutions. Different examples were mentioned such as the use of concept maps for implementing guidelines (safety and environmental guidelines, workplace descriptions, etc.), for transferring knowledge in a learning environment, or whenever simple navigation is required. A critical response highlighted the problem that concept maps are transparent presentation techniques, but cannot be successfully applied to all kinds of users.

4.4 Significant relationships

Correlation analysis (to measure the strength of linear association between variables) provided further insight into the data. However, only significant correlations ($r > 0.5$) will be discussed (Keller and Warrack, 2000; Saunders, Lewis & Thornhill, 2003).

From the correlation analysis it is to be noticed that employees of a specific department prefer specific search methods when searching for the required knowledge. For example, a consultant uses more brochures ($r = 0.5$), while the private customer consultant prefers the company's intranet (especially the news service) to search for new products ($r = 0.51$) and developments in financial markets ($r = 0.55$).

People from the insurance department of the company are generally not optimistic about the use of concept maps, as indicated by the positive correlation coefficient of 0.6 with the negative response to the questions regarding the use of concept maps for sharing and acquiring individual knowledge. Surprisingly enough, there is also an intermediate relationship ($r = 0.6$) between a negative response to the use of concept maps for sharing and acquiring individual knowledge and people who have worked between 3 to 5 years for the company, probably due to previous training or educational backgrounds of the employees. More specific reasoning will require more detailed research, but the current findings can already be used to identify these groups of employees as target groups for special seminars, if concept maps were to be implemented.

The analysis also indicated that there is no significant relationship between age and the knowledge of concept maps, which is surprising, because it is a relatively new method of representing knowledge.

4.5 Creation of concept maps

To evaluate the value and possible applications of concept maps in the company various concept maps were created through interviews with company experts and team discussions to capture knowledge in their specific domains, *inter alia* industry analysis, private banking, and credit evaluation process maps. Form these exercises it became evident that although very valuable in knowledge management, concept maps are not able to fulfil all the tasks of a knowledge management system. This is probably because concept maps were not intended to provide all the functionality of a knowledge management system. However, concept maps do have an essential significance in knowledge gathering, job descriptions, training and seminars, presentations, as discussion support tools, and project work such as workflow management. The advantages of concept maps are their cognitive use and understanding, their self-explanatory structure, the interactivity with the user, and the implementation of multi-media in combination with special layout features.

5 Conclusions and recommendations

5.1 Conclusions

Based on the research it can be concluded that a knowledge management system within the banking and insurance company must provide a broad spectrum of knowledge. This need led to one of the major issues the company currently faces, namely the huge variety of knowledge sources available to employees. Users are presently overloaded with a large amount of single knowledge sources without proper linkage or a unified search functionality, which is able to access the different sources and to deliver high quality results.

Although the company has implemented sophisticated information system technology, it provides only limited knowledge management facilities to its employees. Employees are able to publish and share specific knowledge in the Lotus Notes environment, on the bulletin board, “info-tiles”, and via e-mail. Lotus Notes provides a good information management system, but is basically used as a document management, e-mail and news distribution system in the company. Although these functionalities are relatively sophisticated, the system lacks substantial search functionality and a workflow management facility. The documents are not connected to cases, processes, or current projects in the company. The provided tools for knowledge gathering and knowledge distribution are thus currently not properly used for knowledge management and function more as an electronic newsletter.

The overall response to concept maps was positive, and provides a good starting ground for future implementation. The response to the idea of applying concept maps for the sharing and acquiring of knowledge was very positive, while the willingness of employees to work with a new technique was high - significant factors for the success of implementing a new knowledge management system. This positive response is further supported by the observation that although the company employs relatively young people – people who are more likely to change jobs for career reasons - the period of employment in the company is relatively long, which creates a good working environment, corporate identity, and stability for the implementation of a knowledge management system. The high acceptance of concept maps, especially amongst the 44% of respondents who are familiar with it, can mainly be attributed to their ease of use, logical navigation, and cognitive approach.

From the above-mentioned research and the present use of concepts maps in the company it became apparent that concept map technology provides excellent facilities for knowledge sharing and acquiring processes in the banking environment. Experts, consultants, professional investors, as well as other employees, can make their knowledge available to employees working in remote places, or other employees who want to acquire professional knowledge. The most important kinds of expert knowledge in the company are: investment strategies; portfolio management; and customer relations. Professional brokers, for example, have a vast amount of knowledge of development in financial markets. The majority of their knowledge is due to experience, while a smaller part of their knowledge is gained from books, magazines, or lectures. To gather this experience in connection with established knowledge; market indicators, such as industry growth rate; and other influential factors, are the aim of concept maps. In this context it is important to gain knowledge not only from leading brokers in the company, but also from brokers with less experience and knowledge of financial markets. Concept maps from leading brokers can be used to establish a common standard throughout the company. Maps from less experienced brokers can be utilised to detect possible weaknesses. The results of the correlation analysis indicated that the different requirements pertaining to job category should be taken into consideration as it can lead to different solutions, such as a special concept map database for stock brokers in the company.

As the empirical research and interviews indicated, concept maps are not only suitable for corporate knowledge management purposes, but can also be used as an individual knowledge management tool for the storing of knowledge and personal thinking.

The information technology infrastructure of the company that was researched is an excellent platform for implementing concept maps. Most client computers are “fat” clients with their own hard disk and processor capacity. All work stations are connected to a local-area-network and thus to the various databases, as well as to all external information and knowledge sources. The Lotus Notes environment is able to present hypertext mark-up language documents which can also display concept maps. A planned, web-based knowledge management system creates an even better environment for the use of concept maps.

Benefits to the company could be immense. Concept map technology could support the present informal transfer of knowledge in the company by capturing the expertise of colleagues. Although this informal transfer has a positive social component, it is time consuming, inaccurate, inefficient, and the distribution to all parts of the company is not guaranteed. If concept maps are used within Lotus Notes or in a web application, tacit knowledge about best practice and processes could more easily be captured, stored and transferred to colleagues because the content can be visualised. Eventually work processes in the company would be streamlined and the efficiency of all employees and project teams would be increased. The employees would be able to offer a better final product to customers because they would draw on collective knowledge to create value for the customer and the company. These advantages would also be valid for the outcome of team projects.

Concept map technology is an enabler of many new possibilities, and can greatly contribute to creating and sustaining competitive advantage for the company in the banking and insurance industry. However, a knowledge-centric approach requires not only the necessary information technology, but also an environment conducive to knowledge creation and sharing. Fundamentally, as was pointed out by the research, the company already provides a good environment for knowledge sharing, and employees possess openness and a high tolerance for newly developed techniques.

5.2 Recommendations

In order to successfully implement knowledge management measures in the company, the value of knowledge must be recognised, especially by top management. The company currently emphasises information technology and the dissemination of information, but does not yet realise the value of knowledge management in creating a competitive advantage by improving internal processes, customer services and products, and by creating a good environment for employees. Without the recognition of the importance of knowledge management, an essential backbone of all business processes would be missing. Most business activities, from important strategic decisions, to basic investments, measuring performance, or creating the right company culture, are based on knowledge. Hence, the combination of different knowledge sources into one, strong, company-wide knowledge base plays an important role in the company’s future success.

There is no doubt that concept maps can fulfil this role as a single knowledge management application with a knowledge base consisting of maps with a variety of knowledge from different employees and departments. A single knowledge base will provide a tool for capturing, modeling, preserving, and sharing of knowledge by all employees, as well as standardising the company’s knowledge products and providing all employees with the required knowledge necessary for increasing the quality of the final product or service.

Although concept map technology at the current stage of development is able to provide very important support in the management of knowledge, not all functions within the wide spectrum of a knowledge management system are provided. It is therefore recommended that concept maps within in the banking and insurance industry should be implemented into bigger applications in order to maximise the utilisation of the valuable functions of concept maps in combination with the functionality of other applications.

However, despite missing functionality, concept maps can be advantageous tools to be implemented in the banking and insurance industry. They are easy to understand and use, because they describe concepts and connections in a cognitive way. The users do not need to learn guidelines or rules beforehand as most of the maps are self-explanatory. This guarantees high overall acceptance of concept maps. The implementation of concept maps as part of a company’s knowledge management system is one successful step to be taken towards obtaining and sustaining competitive advantage.

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THE EFFECTS OF CONCEPT MAPS ON REQUIREMENTS ELICITATION AND SYSTEM MODELS DURING INFORMATION SYSTEMS DEVELOPMENT

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Abstract. There are many problems associated with the development of information systems. Requirements elicitation is the phase of systems development when the systems analyst attempts to understand the user(s) concept for a particular system. Problems encountered or left unsolved from the requirements elicitation phase may worsen during the remainder of the systems development project. At the heart of the process is the need to create a shared understanding between the user and the analyst. One method for creating a shared understanding is the creation of a joint concept map by the parties involved. It is hypothesized that combining concept maps with requirements elicitation in an experimental setting will show the benefits of incorporating this technique into the requirements elicitation phase of systems development. An experiment was conducted involving analysts and users working together as a dyad across three treatment groups. The results indicate that the concept map did not assist the analysts during requirements elicitation. These findings are in the opposite direction of existing theory, prior research, and the hypotheses of this research.

1 Introduction

Successful information systems development depends heavily on the interaction of the users and systems analysts (Green, 1989). Due to the misinterpretation of and changes in user needs, however, information systems are constantly undergoing costly re-designs (Kara, 1997; Scott, 1988) which cause ill will between the users and systems analysts. The ability to improve this process is a major concern to the entire information systems development industry, primarily due to the monetary gains (and lack of monetary losses) from building the system correctly the first time (Kara, 1997).

During requirements elicitation, the analyst attempts to elicit and understand the needs of the user(s) and the organization. While requirements elicitation is an extremely difficult phase of systems development, it is one of the least supported (Jeffrey & Putman, 1994; Kim & March, 1995). It is during this phase, and not later in the development process, that the analyst must fully understand user expectations and the goals of the system (Holtzblatt & Beyer, 1995). With the proper requirements, the rest of the development process can proceed and lead to the final system. However, an incomplete requirements elicitation phase may hinder the successful completion of the rest of the development process.

Specifically, poor or error-prone communication between the user and analyst remains a major problem (Byrd et al., 1992; Marakas & Elam, 1998; Tan, 1994), even after several decades of research on improving requirements elicitation (Ackoff, 1967; Guinan et al., 1998). This lack for a shared understanding between the user and analyst may be corrected through the use of mental models during the requirements elicitation process. Mental models have been shown to be effective at creating a shared understanding between multiple individuals in many fields (Hoover & Rabideau, 1995; Malone & Dekkers, 1984; Trochim, 1989), thereby providing an impetus to apply them to information systems development.

2 Theory

Teichroew (1972) put forth the original call to improve communication between the user and analyst, and this need has remained strong within systems development research (Byrd et al., 1992; Marakas & Elam, 1998), and specifically regarding the creation of a shared understanding between the user and analyst (Butterfield, 1998; Tan, 1994). Shared understanding occurs when individuals communicate on a particular topic and then subsequently have the same understanding of that topic (Tan, 1994). Failure to achieve a shared understanding may be due to one or more of the following: a misinterpretation of verbal communication (Fraser, 1993; Tan, 1994); a misinterpretation of nonverbal communication (Foa et al., 1981); or a lack of communication in the first place.

These misinterpretations, or miscommunications, need to be repaired during communication in order to achieve a shared understanding (Schegloff, 1991). However, repairing the miscommunications does not need to be done verbally, as "any methodology that can improve interaction and communication within a group should improve the sharing of perspectives and reduce miscommunication," (Massey & Wallace, 1996, p. 256). This includes nonverbal techniques such as gestures and pictures. Neilson & Lee (1994) specifically call for the combination of natural language (verbal) and graphics (nonverbal) as the means for reaching a shared understanding of the topic. Therefore, concept maps are suggested as a technique for creating a stronger shared understanding between the user and analyst during requirements elicitation.

A concept map is a form of mental model – external models of a person's internal cognitive representation of his/her structural and conceptual understanding of a domain (Craik, 1943). Concept mapping, specifically, has been used in many fields, such as education, psychology, and management (Fraser, 1993; Novak, 1995) to visualize the mental "map" of concepts and their relationships, as well as the structure and hierarchy of these relationships. Concept maps can aide in "making externally explicit the individual's understanding of her cognitive structure" (Fraser, 1993, p. 40). Much of our knowledge is based on the understanding of the relationships among concepts within a domain (Goldsmith & Johnson, 1990), and concept maps, as structured representations, capture these relationships better than other techniques (Markham et al., 1994).

Concept maps consist of concepts (represented as nodes) that are connected to one another showing their relationships. The concepts themselves are words and terms representing events, objects, ideas, and even emotions regarding the particular domain. The relationships, represented as the connecting lines, state that the concepts are conceptually and logically related in some way.

When one person communicates her conceptual understanding of a topic to another individual through a concept map, there is a greater chance of achieving a shared understanding and reducing miscommunication (Fraser, 1993, Rewey et al., 1989). Concept maps have been shown to increase team performance (Blickensderfer et al., 1997) and collaboration (Howard, 1989). Trochim (1989, p. 1) argues that "concept mapping encourages the group to stay on task, results in an interpretable conceptual framework, expresses this framework in the language of the participants, yields a graphic or pictorial product, and improves group or organizational cohesiveness and morale."

It must be noted that concept maps are not intended to replace other methods of requirements elicitation. Concept maps are a technique to be used for representing the requirements and the business situation in an alternate manner, making the entire situation more understandable to the parties involved – the user and analyst – by creating a shared understanding. In the end, concept maps will provide a more complete understanding of the situation by combining the traditional verbal and text-based interview method with the pictorial map with few structural limitations.

3 Prior Research

Several researchers have used mental models in an attempt to improve the requirements elicitation process. Montazemi & Conrath (1986) showed benefits of using cause-effect maps during requirements elicitation, though they did not use analysts in their experiment. Instead, the researchers created the maps after interviewing real users, and then used the maps to create an operational system for the users. While shown to be effective for understanding the user and the complex relationships that were part of the domain, as well as easy to use, the cause-effect maps were not compared to any other technique, nor were they able to incorporate non-causal relationships.

Browne et al. (1997) also used mental models to successfully elicit a higher quantity and a higher quality of information from users, and in this study there was a control group with which to compare the results. Again, however, no analyst was part of the experiment as the researchers created the maps. Massey & Wallace (1996) also found mental models to have positive effects on problem definition, this time in a group setting. Burgess et al. (1992) showed that mental models were able to assist in overcoming communication obstacles during requirements elicitation, though again, the researchers created the maps and then showed them to the users.

McKay (1998) studied real users and real analysts in an action research setting and found that cause-effect maps increased shared understanding as well as provided an overall understanding of the situation and its scope. However, there were no comparisons to other techniques or any control group, leaving the results hard to interpret.

This current study will build on McKay (1998) and Burgess et al. (1992) by validating the use of mental models (specifically concept mapping) in a laboratory setting. The concept map will help the user express in a non-verbal form what is needed and help the analyst understand in a non-verbal form what needs to be done.

The concept map will serve as a bridge between the user and the analyst who may come from very different backgrounds, experiences, perceptions, and styles.

4 Hypotheses

This research proposes to combine (a) the need for a shared understanding between the user and analyst and (b) the need for the requirements elicitation process to be improved with (c) concept maps as the technique for this improvement.

Newburn et al. (1997) and Rewey et al. (1989) have shown that concept maps lead to a greater recall ability of the concepts modeled because their spatial nature simplifies complex concepts and enhances other concepts, and their structure aids future organization and recall via this spatial processing. Therefore, when concept maps are used during requirements elicitation, this recall effect should also be present and should be apparent during the subsequent drawing of the Data Flow Diagrams (DFDs) by the analyst. The effect should be enhanced since the analyst has the concept map in front of him/her as opposed to most previous studies where the map was not available during recall tests. This higher recall of the requirements and other information present in the concept map will lead to greater accuracy in the DFDs constructed by the analysts when user-analyst dyads use concept maps. This is expressed as Hypothesis 1.

H1: Analysts from dyads using concept maps as part of the requirements elicitation process will produce models of higher accuracy than analysts from dyads not using concept maps as part of the requirements elicitation process.

"Shared understanding of information requirements is argued to lead to greater confidence that the requirements are 'right', leading ultimately to 'better' information systems being developed" (McKay, 1998, p. 141). Since concepts maps are hypothesized to increase shared understanding, they are therefore also hypothesized to increase the analyst's level of confidence in his/her models. This prediction regarding perceived accuracy is expressed as Hypothesis 2.

H2: Analysts from dyads using concept maps as part of the requirements elicitation process will rate the perceived accuracy of their models higher than analysts from dyads not using concept maps as part of the requirements elicitation process.

5 Methodology

An experiment was conducted with dyads of simulated users and simulated analysts. The experiment took place in a laboratory setting to increase the precision and control of the measurements. The concept map is both a new technique (to the analyst) and a context-specific technique in that it is relevant to the task scenario and the production of the DFD. Therefore, the analysts in the concept map treatment group (Mx) were trained in a technique that is New and Contextual.

To eliminate the possibility that the results are caused by either the training in something new or the training in something relevant to the task, two additional treatment groups received training as follows. One group (Cx) was exposed to an interaction with the researcher using graphics to present material that was new but that was not contextual to the experiment – New and Non-contextual. A third treatment group (Dx) was exposed to additional rules and procedures regarding the creation of DFDs, also in a graphical and interactive nature, which was Non-new and Contextual. To eliminate the possibility that the training in concept mapping itself is the reason for any of the results, all three treatment groups received a similar amount of exposure and interaction. Data was collected from 8 dyads in each treatment group.

The users were recruited as volunteers from the senior-level, non-IS courses in the undergraduate program of a large, midwestern business school. Analysts were recruited from the senior-level, undergraduate IS courses at the same business school and had already completed at least one (and possibly two) systems analysis and design courses. All analysts received approximately 25 minutes of training and exposure to additional material (as described above) before they were given the scenario. The analysts that were assigned to the concept mapping group received training on creating concept maps based on Novak and Gowin's (1984) and Novak's (1998) introduction and training technique, though adjusted based on Shavelson et al.'s (1994) and Taber's (1994) modifications. Each analyst in this treatment group was given a short measure of his/her understanding of the components and rules regarding concept mapping. Following the training session, the analysts were given an abridged version of the scenario to use as a basis for discussion in the upcoming session with the user. While the analysts were receiving the appropriate training, the users received a full description of the scenario. They were told that they were to take on the role of one of the users of this system and to use the given information and nothing else. Before beginning the session with the analyst, the user was given a short test to assess his/her understanding of the scenario and his/her role in the upcoming session with the analyst

The dyads met for as long a period of time as they (the two individuals) felt necessary. Fatigue did not appear to be a factor for any of the analysts or users. The entire session was videotaped and timed, though the dyads were not aware of the timing. When the dyads felt that they were finished, the users were asked to leave and the analysts began to construct the DFD of the system. This, too, was timed unobtrusively.

6 Results and Analysis

Throughout the remainder of this document, the three treatment groups will be referred to as follows: **Control** – the group that received new and non-contextual material; **DFD** – the group that received additional exposure to DFD rules; and **Map** – the group that received training in concept mapping. The DFDs produced by the subjects were compared with the correct Data Flow Diagram and scored. Two independent judges familiar with the specific scenario conducted the evaluation. The inter-rater reliability was found to be 0.931. When the two judges' scores were not in agreement, the researcher reviewed the two coding forms in order to ascertain and agree on a final score for that Data Flow Diagram.

The concept maps were scored for the number of nodes, the number of links, and for the complexity of structure (extra links). To accomplish this, a common coding scheme was developed in order to accurately compare each map to one another and not to double-count or miss any nodes or links. An independent judge created this coding scheme so that if one map contains the term "employee" and another map contains the term "worker," the two maps could be compared based on the common concept.

6.1 Hypothesis 1

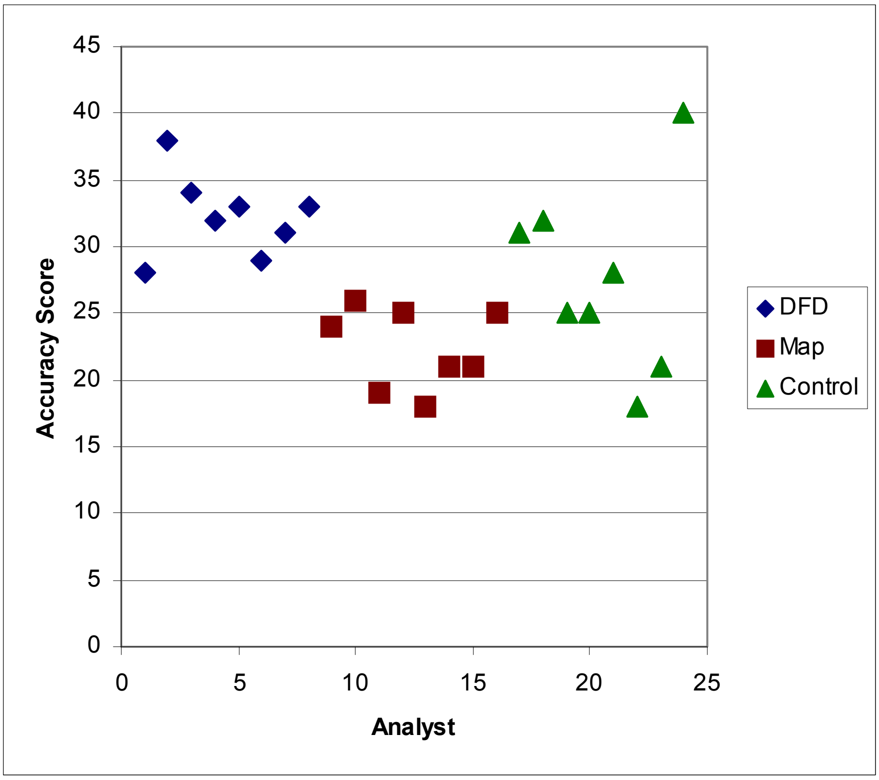

Figure 1. DFD Accuracy Scores Grouped by Treatment

H1 concerned the overall accuracy of the Data Flow Diagrams produced by the analysts following their session with the user. Specifically, this hypothesis stated that the analysts in the dyads using concept maps would create DFDs of higher accuracy than the analysts in the other dyads. The data for testing this hypothesis came from the Accuracy scores for the DFDs as described above. The p-value of 0.002 indicates that there is indeed a significant difference between the groups. Another way to view this data is to look at the individual DFD Accuracy scores as mapped against the treatment groups. As seen in Figure 1, all of the DFD group's scores were higher than all of the Map group's scores – there is no overlap between these two groups. In addition, the scores from the Control group are spread throughout the combined range of the DFD and Map groups. This figure clearly shows the Accuracy differences between the three groups, but most notably between the DFD and Map groups.

The data collected were significantly in the opposite direction of the hypothesis. The Map group's DFDs were significantly less accurate than even the DFDs from the Control group. In summary, Hypothesis 1 is rejected as both the DFD group and the Control group had higher DFD Accuracy scores than the Map group.

6.2 Hypothesis 2

H2 concerned the analysts' perceived accuracy of their Data Flow Diagrams. Specifically, this hypothesis stated that the Map analysts would have higher perceived accuracy ratings of their Data Flow Diagrams than the analysts from the DFD and Control groups. The data for this hypothesis were gathered on the post-experiment questionnaires given to the analysts. The analysts were asked to indicate their perceived accuracy on a 0-100% scale and to explain any rating that was less than 100%. No analyst had a ranking of 100% – the range was between 50% and 98%.

The ANOVA indicates an overall difference among the three treatment groups (p-value of 0.021). While the means are quite different for all three groups, the Map group's ratings were not significantly different from either of the other groups' ratings.

Besides the perceived accuracy scores, the correlations between perceived accuracy and "actual" accuracy were analyzed. The overall correlation coefficient was 0.199, indicating only a slightly positive correlation. However, the individual correlations within treatment groups revealed very interesting results. The DFD group (-0.317) and the Control group (-0.127) both had negative and non-significant correlations, while the Map group (0.814, p-value of 0.014) had an extremely high positive correlation.

In summary, Hypothesis 2 is rejected as there were no significant differences in Perceived Accuracy between the Map and Control groups or between the Map and DFD groups.

6.3 Content Analyses

The concept maps can be analyzed in terms of the number of concepts (nodes) they contain, the number of links between the concepts, and the complexity of the structure. The complexity of the structure is defined as the number of links above the minimum required to connect all of the concepts linearly that are present on a given map. Table 1 shows the descriptive statistics for these three variables.

	Mean	*Standard Deviation*	*Maximum*	*Minimum*
Nodes	12.75	5.600	22	6
Links	18.5	8.246	34	10
Complexity	6.75	3.991	13	0

Table 1. Descriptive Statistics for Concept Maps

It is clear that given the identical introduction and training to concept mapping, analysts (with their user) still created very different concept maps in terms of these numbers, let alone the actual content. The "Maximum" numbers in Table 1 are all from the same concept map, as are the "Minimum" numbers for Nodes and Links. Correlations between DFD Accuracy and the number of nodes, number of links, and concept map complexity found no significant correlations.

There were 29 unique (appearing on at least one map) concepts across all of the concept maps, and each concept appeared on an average of 3.5 individual maps, or nearly half. Of these concepts, only three appeared on every map – Accounts Receivable, Credit Clerk, and Warehouse. This is interesting considering that the Order Entry Clerk played a very prominent role in the scenario and the Customer was also a major figure. However, the omission of certain concepts from one of the concept maps does not imply that this particular map is less accurate than any other map.

7 Discussion

The hypotheses were based on the prior literature and theories regarding the combination of requirements elicitation and concept mapping, but the results do not follow from the theories. Knowing that the concept map had a negative effect on the Data Flow Diagram accuracy, the perceived accuracy results are very interesting. Perceived accuracy is important because it is a measure of the analysts' level of confidence in their own work. It could be argued that these ratings are artificially inflated as a result of a desire to not rate your own work below average. However, there were still differences between the treatment groups in terms of the perceived accuracy ratings, and significantly so between the DFD and Control groups. High perceived accuracy ratings for the Map group would have indicated that there was something about the concept map that boosted the confidence of the analysts. Though the Map analysts' perceived accuracy was not the highest, and was also not significantly different from either of the other treatment groups, the interesting part is the correlation between perceived accuracy and actual accuracy.

The Map analysts were very accurate predictors of their actual accuracy (correlation of 0.814, p-value of 0.014). The other two groups had correlations that were not significant and were negative. The Map analysts seemed to know how much they knew and how much of the "correct" Data Flow Diagram they were able to create. In the other two groups, the analysts were less clear as to how much they knew. Still, the fact that the Map analysts' Data Flow Diagrams were significantly less accurate than both of the other groups' DFDs makes this correlation hard to interpret. These analysts were excellent predictors of accuracy, even though their accuracy was not very high!

The question remains, however, of why the concept map did not have the hypothesized effects. Based on the concept map introduction and training sessions, the results from the concept map quizzes given to the Map analysts, and the concept map analyses, the analysts understood the technique of concept mapping, and they created the concept maps based on the instructions given to them. However, it is possible that the analysts understood how to create a concept map and the technique of concept mapping, but they didn't understand how to apply the technique in order to effectively use a concept map. Similarly, it may be that mastery of the concept mapping technique may take much time with continual exposure and practice as it is part science and part art form. It appeared in this study, however, that subjects had received and grasped enough training in concept mapping that there should have been some benefits derived from the technique if any were to be derived. The training used in this study was based on the previous literature in concept mapping from Novak (1998) and Novak & Gowin (1984). Future studies with different training techniques may be able to rule out whether the degree or nature of training is in fact the reason for the non-support of the hypotheses.

The Data Flow Diagram exposure focused the DFD group analysts onto the task of creating a Data Flow Diagram and so they were acting, thinking, and questioning with that goal in mind. The Map analysts knew that they had to create a concept map with the user and so they weren't able to focus on the end-result of the Data Flow Diagram as much as the DFD group. Therefore, their questions and thought processes weren't as polished or "on target," and the concept map couldn't make up the difference. This would explain higher scores for the DFD group over the Map group, but this does not explain the higher scores for the Control group over the Map group in terms of Data Flow Diagram accuracy. At worst, the Map and Control groups should have performed equally well if the only reason the DFD group performed better was due to the extra exposure to Data Flow Diagramming. Since the Control group also outperformed the Map group, there must have been something else going on with the concept map to cause lower scores.

It is possible that the exposure to concept mapping simply interfered with the analysts' ability to think about DFDs and create DFDs. The concept maps may have prevented adequate reactivation of the analysts' more traditional knowledge of DFDs, hindering their DFD modeling ability and resulting in the lower DFD Accuracy scores. This negative priming of the analysts' prior knowledge due to their exposure to an unrelated technique is consistent with Dalrymple-Alford & Marmurek's (1999) study of priming effects. The analysts that were given additional DFD exposure had their ability to think about and create DFDs activated/enhanced, resulting in the higher DFD Accuracy scores. The Control analysts, who received no exposure to either concept mapping or DFDs, did not have their DFD knowledge hindered or enhanced.

8 Conclusion

The main concern of this experiment was the accuracy of the Data Flow Diagrams produced by the analysts. Not only was the hypothesis incorrect, but both of the other groups had Data Flow Diagrams of significantly higher accuracy than the Map group. There were differences between the treatment groups in terms of the perceived accuracy ratings, and significantly so between the DFD and Control groups.

Concept mapping theory, which states that they are universal communication tools, did not hold in this context. Therefore, additional studies need to be conducted to further investigate the incorporation of concept mapping into requirements elicitation and to determine if concept mapping and requirements elicitation can be combined effectively. Possible manipulations to this current study include varying the scenario's length and/or complexity, varying the level of training in concept mapping given to the analyst, varying the level of training given to the user, and varying the systems experience of the analyst.

While there were results here that were in the opposite direction of the hypotheses, this study still makes a contribution to the Information Systems literature and to the Concept Mapping literature. First, this study shows that a very useful technique for enhancing communication and creating a shared understanding does not work in all situations and contexts. Without positive accuracy results (or even non-negative accuracy results) in this or in similar contexts, the concept map should not be utilized given that Data Flow Diagram accuracy is the measure that will strongly influence the remainder of the systems development project. Second, this study further supports the fact that requirements elicitation is a vital part of information systems development and that problems remain with the communication between the analyst and user – i.e., not all techniques for communication will be successful when used in a requirements elicitation session. Finally, this study suggests that perhaps all that is needed for increased DFD modeling accuracy is more and/or more formal training in Data Flow Diagramming.

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THE POWER AND BENEFITS OF CONCEPT MAPPING: MEASURING USE, USEFULNESS, EASE OF USE, AND SATISFACTION[1]

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Abstract. The power and benefits of concept mapping rest in four arenas: enabling shared understanding, the inclusion of affect, the balance of power, and client involvement. Concept mapping theory and research indicate concept maps (1) are appropriate tools to assist with communication, (2) are easy to use, and (3) are seen as beneficial by their users. An experiment was conducted to test these assertions and analyze the power and benefits of concept mapping using a typical business consulting scenario involving sixteen groups of two individuals. The results were analyzed via empirical hypothesis testing and protocol analyses and indicate an overall support of the theory and prior research and additional support of new measures of usefulness, ease of use, and satisfaction by both parties. A more thorough understanding of concept mapping is gained and available to future practitioners and researchers.

1 Introduction

Originally developed in 1974 as a technique to make sense of data gathered in clinical interviews (Novak & Musonda, 1991), concept mapping has been used in numerous ways in education, psychology, and organizational settings (Fraser, 1993; Novak, 1995). The power and benefits of concept mapping rest in four arenas: enabling shared understanding, including affect, balancing power, and involving the client. By enabling an individual to express one's domain understanding to others, a shared understanding is created between the individuals. It must be noted, however, that shared understanding does not mean agreement, but rather an understanding of each other's position. Concept mapping facilitates the creation of this shared understanding and reduces the miscommunication between individuals (Fraser, 1993). Concept maps are not limited to the inclusion of facts or factual understanding. Affect – emotions, feelings, and other affective concepts (e.g. frustration, challenge, fear, anger, joy, fulfillment) – has a natural place in concept mapping, as affect is an integral part of thinking and acting (Novak & Gowin, 1984).

In a traditional consulting situation, the trained consultant/analyst (the expert) is seen as much more powerful than the client who is in need of assistance with some situation. Clients will often resist the consultant (Marakas & Hornik, 1996) and/or feel dependent towards the consultant (Fraser, 1993) as a result of this power imbalance. Concept maps are able to correct this imbalance and at the same time create a sense of responsibility on the part of the client (Mazur, 1989). Finally, concept mapping can increase the overall participation of the client, user, employee, etc. when the concept map is used supplementally. This is related to the concept of the power relationship because if the client feels as though s/he has no power and no responsibility, the client's participation will likely be very minimal. However, if a sense of responsibility can be created or enhanced, the client will likely participate to a greater extent.

This leads to the following general research questions: What are the effects of the use of a concept map on enabling a shared understanding, including affect, balancing power, and involving the client? By what means does the concept map achieve these benefits? In addition, in what ways do users perceive the concept map, and how does the concept map affect communication?

2 Concept Mapping

Concept mapping is a technique to let one person convey meaning to another in a visual format, and concept maps have been shown to foster a joint understanding between two individuals viewing the same map (Novak, 1977; Malone & Dekkers, 1984; Hoover & Rabideau, 1995; Novak, 1998). The concept map is believed to enhance recall and memory, aid in negotiation and balancing of conflicting needs, and create mutual understanding.

Concept maps are generally used to either express a conceptualization of an issue to others (Fraser, 1993; Glynn, 1997) or to attempt to understand the conceptualization of an issue by others (Suen et al., 1997; Thatcher & Greyling, 1998). They allow collaboration in problem solving by people in different disciplines or situations

[1] This paper presents a condensed version of a study previously published in the *International Journal of Science Education*, http://www.tandf.co.uk/journals.

(Howard, 1989). They are effective at increasing team performance (Cannon-Bowers et al., 1993; Hinsz, 1995; Blickensderfer et al., 1997) and at increasing shared expectations and shared understanding (Rewey et al., 1989; Kraiger & Wenzel, 1997). Trochim (1989, p. 1) argues "concept mapping encourages the group to stay on task, results in an interpretable conceptual framework, expresses this framework in the language of the participants, yields a graphic or pictorial product, and improves group or organizational cohesiveness and morale."

Describing an individual's cognitive structure through other techniques such as "a spoken narrative, an outline, a written summary, formal and informal conversation, a flowchart, etc." is limited in that these techniques are linear and unable to depict the complexity of the relationships between concepts and ideas (Fraser, 1993, pp. 40-41). The process of creating and using the map is as important as the content of the map. For example, "through the actual process of constructing a concept map the individual can also make new connections and recognize concepts which should be added" (Fraser, 1993, p. 33). Concept mapping will allow for a very inclusive diagram of the scenario with few structural limitations.

Creating and drawing these maps is one exercise, but being able to assess them is important for understanding them and comparing multiple maps to one another (Novak & Gowin, 1984; Shavelson et al., 1994; Dorough & Rye, 1997). In general, concept maps can be measured either quantitatively or qualitatively (Rink et al., 1994; Rowe & Cooke, 1995), and both techniques play a role in this study.

3 The Experiment

3.1 Hypotheses

The satisfaction of the users of a new technique or process is an important criterion in the overall evaluation of that technique or process (Vennix & Gubbels, 1991). Based on the literature that found motivation and concentration to have increased after using concept maps (Hall & O'Donnell, 1996), we believe that the use of the concept map will be perceived as beneficial to the parties involved. This prediction is also based on the literature that suggests that concept maps are helpful in gaining a shared understanding (Fraser, 1993; Taber, 1994). This prediction is not concerned with the entire communication session, rather, just with the use of the concept map as a technique within the session. Though not necessarily a direct benefit of concept mapping, Taber (1994) reports that students had positive comments towards concept mapping in terms of both a) the task, because concept mapping is different, interesting, and brings back "memories" of other concepts, and b) in terms of their own learning, because the maps show what you know and the links actually evoke new concepts, a point also made by Fraser (1993). This reaction should be helpful when concept mapping is added to a task. We, thus, express Hypotheses 1a and 1b below.

H1a: Analysts using concept maps will perceive them to be a beneficial part of the communication process.
H1b: Users using concept maps will perceive them to be a beneficial part of the communication process.

As previous studies have shown cognitive maps to be successful communication tools (Burgess et al., 1992; McKay, 1998), there should be a greater sense of satisfaction with the entire communication process for analysts and users who employed the concept map. In other words, analysts and users from dyads that used a concept map to assist their communication will feel that they were better able to communicate with each other and that the whole session was more successful. This is expressed in Hypotheses 2a and 2b.

H2a: Analysts from dyads using concept maps will have a higher satisfaction rating of the requirements elicitation session than those analysts from dyads not using concept maps.
H2b: Users from dyads using concept maps will have a higher satisfaction rating of the requirements elicitation session than those users from dyads not using concept maps.

While the inclusion of affect is an important aspect of concept mapping, it is beyond the scope of this study. However, the other three arenas will be tested and analyzed via quantitative and qualitative methods. Concept maps will generate the benefits as indicated, and these are expressed as Hypotheses 3a, 3b, and 3c.

H3a: The concept map will enable shared understanding during the communication process.
H3b: The concept map will create a balance of power during the communication process.
H3c: The concept map will result in increased client involvement during the communication process.

3.2 Methodology

An experiment was conducted with dyads of simulated business professionals – end-users and analysts. The experiment involved two treatment groups: one group that utilized concept maps during the communication session and a second group that did not utilize concept maps. Data was collected from eight dyads in each treatment group. The subjects were recruited as volunteers from senior-level courses in the undergraduate program of a US business school. Analysts were Information Systems (IS) majors and had already completed at least one (and possibly two) systems analysis and design courses where they learned and practiced the techniques of being a systems analyst/consultant. Users were non-IS majors. As such, these groups are representative of the "typical" entry-level analyst and end-user, respectively, that would be involved in a systems consulting project.

The analysts assigned to the concept mapping group received training on creating concept maps based on Novak & Gowin's (1984) and Novak's (1998) introduction and training technique, though adjusted based on Shavelson et al.'s (1994) and Taber's (1994) modifications regarding hierarchy to allow for more flexibility in creating the maps. This training was performed carefully so that the analysts were not biased into creating their concept maps in a certain way or in a certain format based on the training. The analysts were told that they would be required to utilize this technique during their upcoming session with the user. They were told that they may construct the concept map at any point during the session. Each analyst in this group was given a short test of their understanding of the components and rules regarding concept mapping.

Following the training session, the analysts were given an abridged version of a business scenario to use as a basis for discussion in the upcoming session with the user. While the analysts were receiving the appropriate training, the users received a full description of the scenario. The users were told that they were to take on the role of one of the users of this system, and were to use the given information and nothing else. They were told that they would soon be meeting with a systems analyst whose job was to fully understand the workings of the system. They were also told that they were to answer all of the analyst's questions accurately and fully, but were not to provide information on their own (i.e. unprompted), nor were they to provide extra information not contained in the scenario.

The entire session was videotaped. When the dyads felt they were finished, the subjects were asked to fill out an exit questionnaire (in separate rooms) consisting of questions regarding their perception of including the additional technique (only for subjects from the concept mapping group) and their satisfaction with the session.

4 Analysis and Discussion

Throughout the remainder of this document, the two treatment groups will be referred to as Map – the group that received an introduction and training in concept mapping – and Control.

The videotapes of the sessions allowed for protocol analyses to be conducted of the interaction between the analyst and user within the session and the drawing of the concept map. These videotapes of each session were each analyzed and detailed quantitative and qualitative codings were made. These data, alone and in combination with the actual maps and the questionnaires, provide answers to the questions of "what did the participants feel about the map," "what effect did the map have," and "how was the map used."

4.1 Hypotheses 1a and 1b

H1a stated that the analysts (from the Map group) would find the concept map to be a beneficial part of the requirements elicitation process. Similarly, H1b stated that the users (from the Map group) would find the concept map to be a beneficial part of the requirements elicitation process. To measure the satisfaction ratings of the concept map itself, analysts were given the Perceived Ease of Use (six items) and Perceived Usefulness (six items) scales from Davis (1989). Both measures were given on a seven-point Likert scale with a midpoint response of 4.0. The results show strong, positive feelings towards both the Usefulness and Ease of Use of the concept map, and both measures were significantly positive with p-values of 0.004 and 1.828E-05, respectively.

The highest ratings for individual items from the Usefulness scale were from the questions regarding the concept map enhancing effectiveness on the job (6.125) and being useful on the job (5.625). The highest Ease of Use ratings regarded the concept map being easy to learn (6.375) and being flexible to interact with (6.125). Though both measures are predominantly above the midpoint, the correlation between the two measures of 0.329 was not significant at the 0.05 level.

In addition to the Usefulness and Ease of Use scales, the post-experiment questionnaires contained questions to ascertain overall feelings regarding the concept map and its use within the session. The questions concerned perceptions of the concept map's helpfulness in communicating with the other party, representing the requirements of the system, representing the structure and logic of the system, and the role of the concept map in the session in terms of time. In addition, the users were asked whether they were pleased that the concept map was available and whether they would be likely to use a concept map in the future when communicating with an analyst. The four analyst questions and the six user questions were analyzed individually.

All four satisfaction measures for the analysts were significantly positive, further indicating that the analysts felt the concept map was beneficial, helpful, and useful. All six satisfaction measures for the users were significantly positive, indicating that the users in the Map group felt the concept map was beneficial, helpful, and useful, and they were glad the concept map was available in the session with the analyst. In summary, Hypotheses 1a and 1b were both supported as the analysts and users had significantly positive satisfaction ratings for the concept maps.

4.2 Hypotheses 2a and 2b

H2a stated that analysts in the Map group would rate their session satisfaction higher than analysts from the Control group. Similarly, H2b stated that users in the Map group would rate their session satisfaction higher than users from the Control group.

The ten-item scale used to measure the session satisfaction, adopted from Essex (1998), contained questions concerning whether the other party was a good listener, the clarity of the communication, the purposefulness of the communication, and the communication compatibility between the two parties. For the analysts, there was no significant difference (p-value of 0.310) between the Map and Control groups' ratings, though the Map group ratings (5.078) were higher, as hypothesized, than the Control group (4.891). Regarding the users and their session satisfaction ratings, the p-value of 0.403 indicates no overall difference between the two groups. Like the analysts' ratings, the mean for the Map group (4.975) was also slightly higher than the mean for the Control group (4.838). These results seem to say that according to the users, the session with the analyst was no different in terms of communication. Overall, there was a 0.588 correlation (p-value of 0.017) between analyst and user session satisfaction ratings, signifying that both the analyst and the user were generally in agreement with each other regarding their satisfaction with the session.

In summary, Hypotheses 2a and 2b were both rejected as Session Satisfaction for the analysts and users from the Map group were not significantly different from the Control group.

4.3 Hypotheses 3a, 3b, and 3c

H3a stated that the concept map will enable shared understanding during the communication process. The satisfaction ratings from the analysts and the users regarding both the concept map itself and the elicitation session indicate that the concept map was helpful in achieving a shared understanding. The session satisfaction ratings for the analysts and users were significantly positive, and since much of the scale focused on self-reported levels of communication and understanding the other party, these ratings indicate that both groups felt there was positive communication during the elicitation sessions. Furthermore, the analysts and users both had significantly positive ratings of satisfaction with the concept map itself as being helpful for communication and for representing the requirements, structure, and logic of the scenario. These all indicate that the concept map was perceived to be beneficial and perceived to be a technique that would help create a shared understanding.

H3b stated that the concept map will create a balance of power during the communication process. The concept maps seemed to have mixed results. While there was not a large difference in power to begin with (since both the analysts and the users were students from the same business school), there was definitely a sense of a power difference because the users all waited for the analyst to begin the session as if they knew that the analyst was the one in charge. During their introduction to the experiment and the scenario, the users were told that they would be meeting with an analyst, and it is possible that the users assumed that the analyst would be in charge. This difference may not have been as large as a user would experience in the real world when working with a senior analyst from a consulting firm with 15 years of experience, but there was still a gap. In some instances, the analyst was the leader in the creation of the concept map and the user interacted with the analyst in a way that would signify a clear power distinction. However, in other instances, as would be expected, the user and the analyst jointly created the concept map – both in terms of ideas and in actual writing on paper. In these instances the user appeared to feel very much a part of the process and able to contribute equally.

Additionally, the concept map seemed to create a sense of responsibility on the part of the user with regards to the entire process and the eventual end results of the session. In one case, the user actually initialed the final concept map as a display of responsibility and ownership.

H3c stated that the concept map will result in increased client involvement during the communication process. While related to the arena of balancing the power relationship, one is not necessarily required for the other. For example, a great deal of user participation with poor analyst attitudes and communication can still lead to a perception of a great power imbalance. With regard to the user-analyst interactions and to the overall participation of the users, the concept map had a very strong influence. As soon as the analyst brought up the idea of creating a concept map and gave the user a brief explanation or demonstration, the user's posture at the table became more upright and open and the user's engagement with the analyst increased in terms of offering ideas and opinions. As previously stated, several users actually participated in the physical creation of the concept map. Additionally, the very nature of a joint concept map (a map created together by two or more people, as was the case with this experiment) requires that the two individuals agree on the content of the map. Therefore, no matter who was creating the physical map on paper, the other party was asked if they agreed with both the placement of a new concept and the choice of the linking word to link the new concept to an already existing concept. This participation in the creation of the concept map is directly related to the overall participation of the user in the elicitation session.

In terms of the three arenas just discussed, it seems that the concept map worked as expected. It created a sense of shared understanding, it created a balance in the power of the relationship, and it created greater participation by the user. More details can be gained via the protocol analyses.

4.4 Concept Map Creation

The first part of the protocol analyses concerned when the concept map was created. The analysts were told that they must create the concept map with the user at some point during the session but that it was their decision as to exactly when it would be created. Two of the analysts began creating the concept map with the user right away. The other six analysts went through an interview process with the user (asking questions about the scenario) that lasted between two and thirteen minutes before they began creating the concept map with the user.

The next part of the protocol analyses concerned who actually drew the concept map. In all cases, the concept map was a "joint" concept map, meaning that both the analyst and the user participated in the creation of the map in one way or another, as will be discussed shortly. However, in only two of the sessions did the user physically participate in the drawing of the concept map by adding concepts and appropriate relationships. In the other six sessions, the analyst was the only person who physically created the concept map on the piece of paper. This additional participation by the two users reinforces the earlier discussion of the power of the concept map to increase participation, though this was not the only way that participation was increased as a result of the concept map.

During the communication session, the concept map played a very large role in terms of time. The analysts and users spent, on average, just under 19 minutes creating the concept map. The range was from just over 9 minutes to just over 34 minutes. This time was split between drawing the concept map, reviewing the concept map, talking about potential concepts and/or relationships, and reviewing the scenario and other written notes.

It should also be noted that none of the dyads redrew their concept map or started over at any point. (All of the drawing took place on paper with either pen or pencil based on the analysts' and users' preferences.) All corrections or changes made to the concept maps were made on an individual-item basis without starting over or redrawing the whole concept map. In fact, during many of the sessions, there was a lot of erasing and re-drawing of concepts and links as the analyst and user discussed the scenario and the concept map. During the training session with the analysts, they were told that they could use as many sheets of paper as necessary to complete the concept map.

4.5 Concept Map Interactions

Now that we know when the concept map was created, who did the physical writing, and how much time it took to create the concept map, we can look at the interactions between the analyst and user during the creation of the concept map. While the analyst may have done all of the physical writing in most cases, this did not mean that the user was not a part of the process. In four of the sessions, the analyst began the mapping process by explaining to the user what a concept map is, what they do, and what they look like (often using one of the concept maps drawn during the introduction session as an example). In a fifth session, the analyst explained the concept map when they were finished creating it, probably too late to help the user gain any additional understanding. In the other three sessions, the analyst offered no explanation of the concept map, nor did the user ask any questions regarding its purpose, meaning, or use.

In all of the sessions, the analyst began creating the map by writing the main concept near the middle of the paper. (This was a direct result of the introduction and training.) In half of the sessions, the analyst asked the user to help determine the main concept, and when they agreed, the analyst wrote down this concept. From that point, the analysts continued to add concepts and the appropriate linking words to create relationships among the concepts. In six of the sessions, the analyst spoke aloud while creating the concept map (increasing the overall level of involvement as the user knew what the analyst was doing) and asked the user "yes/no" questions to confirm the existence and placement of concepts and the appropriate linking words for the relationships. Based on the user's response, the analyst would either continue to the next concept or relationship on the concept map, or the analyst would ask follow-up questions in order to reach an agreement on what was just drawn. In the other two sessions, as well as in two of the previous sessions, the analyst involved the user to a greater extent in the creation of the concept map by asking open-ended questions so that the user was participating in the actual construction of the concept map. Based on the responses to these questions, the analyst would add concepts and relationships to the concept map. These analysts and users evenly shared the responsibility for adding items to the concept map, whereas in the other dyads, the responsibility was still shared, but the user took on the role of someone with veto power.

During the session, the analyst and user sat on opposite sides of a small table facing each other. Therefore, since the analysts were doing the physical writing on the concept map, it was natural for the analysts to have the map facing them and, as a result, upside-down to the users. However, in several of the sessions, the analysts physically turned the map sideways so that it was partially between themselves and the users. This helped increase a sense of balance of power and helped increase actual participation on the part of the user. In several other sessions, once the analyst and user began creating their concept map, the user sat upright in his/her chair and showed a greater degree of interest in what was happening. Also, in several sessions the interaction between the analyst and the user was very casual, at least much more so than in other sessions. These dyads were laughing at different points and were conversing with very casual tones and gestures.

Regarding the two sessions where the user physically created part of the concept map, in one session, while the analyst was involved in creating a list of potential concepts on a separate sheet of paper, the user began adding concepts and relationships to the concept map. When the analyst finished the list, the analyst noticed (with some surprise) that the user had added items to the map. The two of them then reviewed the additions, discussed them, made some changes, and continued with the process. In the other session, the analyst had the user create a similar list of words. After a few minutes, the analyst began adding ideas to this list. When the list was completed, the analyst had the user begin to add items to the concept map. The analyst noticed that the user was getting "stuck" and was unsure of how to continue, so after a few minutes, the analyst took over and became the main drawer of the concept map. Even so, the user in this dyad was very involved in the creation of the concept map. In a third session, even though the user did not physically create any part of the concept map, the user initialed the paper as an indication of agreement with the content and look of the concept map.

The final interaction between the analyst and the user deals with a final review of the completed map. In five of the sessions, the analyst specifically reviewed the concept map with the user. In these cases, the analyst began with the main concept and continued to describe the contents of the concept map. In at least one instance within each of these reviews, the analyst and/or user decided that a change was necessary to one of the relationships, indicating that there were benefits to the review process in terms of making sure the concept maps were correct and that both parties were in agreement.

4.6 Other Observations

The protocol analyses also enabled several other observations. While drawing the concept map, a few of the analysts included items from the scenario that the user knew very little about. In one case, the user specifically stated that the analyst's question could not be answered, but the analyst still included the items of concern in the concept map and created relationships between them and other concepts. Finally, several of the concept maps were drawn at a very high level, meaning that they contained only the major concepts (such as the main entities within the scenario) and their primary relationships to each other. With one of these high level concept maps, the analyst and user actually discussed several detailed relationships while creating the concept map, but they were left out.

Additionally, by creating the concept map and thereby reviewing much of the material already elicited and discussed, the user was forced to be sure that the information was correct. This review by the analyst in the form of the concept map provided exposure to the information a second (or third) time, and thereby gave the analyst a much clearer understanding of the scenario. This was seen in the way that the analyst communicated with the user while creating the concept map – the analyst stated much more of the relationships by memory without the need to look at notes; the analyst spoke much more coherently and smoothly about the processes and the scenario; and the analyst and user confirmed each other's responses much faster.

There was not one "best" method for creating the concept map that ultimately led to either a larger or more complex map. The protocol analyses of the concept map creation phase indicate that there were very diverse techniques utilized by the analysts in creating the concept maps with the users. It seems that different combinations of interactions, question styles, and activities all produced concept maps with many nodes, many links, and high complexity. This is likely due to the fact that the concept map is a relatively ill-structured technique and there was no uniform technique across the teams. While the concept map is relatively ill-structured, this does not mean that it is not useful nor that it cannot be understood and utilized. By ill-structured, it is meant that there is no single technique for creating a concept map with another person and the process is very individualistic. As the concept map is a very personal (to either one person or multiple people working together) representation of an internal mental model, so are the interactions and choices made while producing the concept map.

5 Conclusion

There are several known limitations to this study. First, as a laboratory experiment, there are aspects of the real world that are not a part of the overall design. For instance, the scenario that is used is not a real business situation, though it is realistic. On the other hand, a laboratory experiment provides a greater degree of control over the subjects, the task, and the measurements. In addition, there are limitations of using students for all of the subjects. However, this choice was made in order to keep the subject populations (analyst and user) as homogeneous as possible to control for covariates, and it follows prior research in systems development (Marakas & Elam, 1998).

This study showed the concept map to be a good communication tool and both parties found the concept map to be beneficial, easy to use, and useful. The power and benefits of concept mapping were realized and measured through both quantitative and qualitative techniques. These are all solid, practical findings for those interested in utilizing this technique to assist communication between two parties.

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FROM THOUGHT TO CONCEPTUAL MAPS: CMAPTOOLS AS A WRITING SYSTEM

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Abstract. The experiences of *global writing,* widely moving through the various categories (music, video, poetry, cinema, theatre, etc.), produce new expression modes, however often excluding and limited to a circle who shares its interpretative keys. The turning point we are now experiencing is from *text to hypertex.* Usually, children learn to read, write, count and draw during the first year of the elementary school and they will do it automatically during their entire life. Many children, on the contrary, are not able to make these correspondences automatic. We now know that these disorders are of a neurobiological kind. According to Chomsky, we are provided with a certain number of typical faculties of the human species. It is the theory of knowledge, not of behaviour. As functional magnetic resonance enables us to see the confirmation – later – of the biological matrix of the Generative Grammar and Universal Grammar principles, ***conceptual maps*** are the most effective scientific tool to identify language acquisition processes, its conceptual development, and the instrumental abilities that ensure the comprehension of written texts for the whole life. For four years, we have been working on the design and implementation of an educational programme, which should continuously accompany children from the age of 3-4 to the age of 12-13: *from formulation of concepts, to the use of conceptual maps.* The corner-stone of this ideal educational process is the common awareness *that the base of any meaningful construction of learning and knowledge is the language, which is the ability of all human beings to conceptually represent the world for themselves, through giving names to it, and that every individual has the right to have appropriate tools to express its endless possibilities***.** The purposes of the research, considered as a starting and arrival point, are the *pleasure of narrating* and the *pleasure of writing***,** which are acquired from the very early childhood and are kept during the whole life, only if there are exercise and satisfaction opportunities. In this context, even for children who are 6 years old (who are able to use the software autonomously)**, CmapTools** was an excellent support for what Roy Harris defines a **writing system** In practice, it works like a narration system, which ensures a complex communication, using several linguistic codes simultaneously.

1 Introduction

In Urbino, some classes of the School I. C. "Paolo Volponi**"**, for four years, we have been working on the design and implementation of an educational programme, which should continuously accompany children from the age of 3-4 to the age of 12-13: from formulation of concepts, to the use of conceptual maps (coordinator of the project for the "area linguistic activities" Liviana Giombini; coordinator of the project for the "area scientific activities" Patrizia Gostoli; the primary teachers involved Andreina Canti, Caterina Picicci, Patrizia Penzo and the nursery teacher Dina Bertozzi).

The corner-stone of this ideal educational process is the common awareness that the base of any meaningful construction of learning and knowledge is the language, which is the ability of all human beings to conceptually represent the world for themselves, through giving names to it, and that every individual has the right to have appropriate tools to express its endless possibilities.

The purpose of our class work is to demonstrate that the *pleasure of narrating* and the *pleasure of* writing, which are acquired from the very early childhood and are kept during the whole life, only if there are exercise and satisfaction opportunities. A real preparation process to the positive children-writing interaction occurs when the conditions wished by Dewey are obtained: *having something to say*, and having *the instrumental capabilities to say it using the selected expression code.*

2 From Text to Hypertext

Normally, writing is only considered as a material action of communication of thoughts, through words and sentences. However, for some time cultural products completely different from books – the traditional support for the production of human thoughts - have been part of daily experience for millions of people.

For at least fifteen years, objects that are completely different from books – hypertextual and interactive objects – are available to children, often offered by parents as reading inducers.

They can be read on a computer screen, are amusing, offer labyrinth narration paths, allow completely different procedures than those offered by a printed book, with a linear and sequential structure.

The experiences of *global writing,* widely moving through the various categories (music, video, poetry, cinema, theatre, etc.), produce new expression modes

The turning point we are now experiencing is from *text to hypertext.*

In this context, even for children who are 6 years old (who are able to use the software autonomously), **CmapTools** was an excellent support for what Roy Harris (1986) defines a *writing system.*

In fact, it materially provides them with the tool to "continue writing" in the most natural way, considering that child's natural writing is of a hypertextual type.
Writing (considering writing as the semiotic ability, controlling the creation of signs, which is *"la faculté linguistique par excellence" for Saussure* (1916) shows all its complexity in children: expression of sequential and linear thought, but also process and reticular thought. As a drawing is the expression of natural hypertextual writing, c-maps introduces and educates individuals to an expert hypertextual writing.

3 Formulation and Representation of a Concept

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 (5 years old), to the acquisition of composition rules of conceptual maps in parallel with the acquisition of writing (6 years old), up to the organization of real knowledge domains (10 years old).
From the very early childhood, children are able to formulate a concept through "touching" the world and giving names to it. Through the cognitive possession of names, the mind "appropriates" reality, almost to confirm what is described in the Genesis (II, 19; XI, 6-9): language is a metaphor of knowledge or exclusion.
Initially, child words are orders and wishes and do not express concepts; on the contrary, they fulfil much more complex functions than it initially appears
For children, who are in a situation of full, frenzied communication learning activities, words are "naturally" a meaning unit, through which they name and think of the surrounding world. They are meaning units they use to play just like they do with Lego bricks. They learn how to speak and then read and write, following the very simple understanding that words are groups of sounds with a meaning, phrases are groups of words with a meaning, and stories are groups of phrases with a meaning.
For children, representing their experiences through words, lines and drawings is a natural process.

3.1 Formulation and Representation of Concepts: age 4-5 years

The attached drawings illustrate what Piaget had already identified: 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". They have a communication value related more to a semiotic than semantic type structure.
These are *stories* from 4-5 year old children who were asked by their teachers to make drawings of "nice words, bad words", "scary words" and "sweet words". For "nice words", Elisabetta - 5 years old – wrote her name, made a drawing of a flower, but also falling snow; as examples of "bad words", a rocking-horse and a car (in the explanation, the teacher noted the comment of the author: rocking-horse causes a child falling; car sliding on ice and provoking an accident); the classification results from the association of negative experience-object. "Scary words": ghost, wolf, bear, belong to the "literary" experience and are the exact correspondence between name and concept.

Figure: "**Nice words – bad words**"

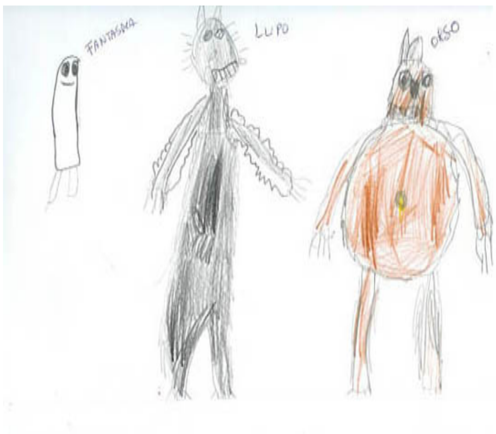


Figure: **"Scary words"**

The following drawing was made by a five and a half year old boy, illustrating "sweet words". We believe it is extremely important, because it is a full example of pre-writing and conceptual narration: facts, illustrated by concept-words, are told and arranged according to a directional order.

Figure: **"Words becoming sweet":** (spontaneous narration of how an apple seed becomes jam)

It makes a picture of the spontaneous transition from a complex but "ungrammatical" "narration" – as children drawings are -, to a linear, logical and sequential narration.
The child remembered and reformulates, in an autonomous and spontaneous way, an experience occurred at school approximately one year before. The space of the sheet of paper receives two different narrations: in the first, on the left, the "story" starts. From apple seeds sown in the garden, an apple tree grows, and many apples on it (it is interesting to notice how wishes and reality are exactly at the same level). In the second half of the sheet, there is a drawing of a table, on which there is a sugar box, a pot full of apples, which boil and become jam, and a jar full of jam. The title of the drawing given by the little boy is: "Sweet words that become very sweet". It is interesting to notice the movement of the brown line at the bottom of the sheet: it goes from left to right, receives, guides and accompanies the writing of the story, almost "miming" the movement of a finger moving following that direction.

4 Writing and conceptual maps at 6 years of age

Usually, children learn to read, write, count and draw during the first year of the elementary school and they will do it automatically during their entire life.
During the very first school months, children make enormous efforts, they learn what we call the alphanumerical structure representing the writing system used, based on the sign-concept correspondence: sound – grapheme; figure – quantity.
Many children, on the contrary, are not able to make these correspondences automatic.
In that case, learning disorders appear, such as dyslexia, which are often associated with other learning disorders, such as dysorthography, dysgraphia, dyscalculia, difficulties in learning too often attributed to behavioural problems or, in the most serious cases, with intellective deficits classified as "mental retardation".
It is estimated that in Italy 3 to 5% of the population is affected, but 50% of these people are not aware of that, and practice shows that usually at least one child per class has one or more disorders related to this problem.
Through functional magnetic resonance we now know that the nature of these congenital disorders is neurobiological, and that the brain has enormous compensation capabilities; if a given brain area cannot do something, another area can learn how to do it.
When Noam Avram Chomsky, laid the foundations of his philosophical belief, according to which we are provided with a certain number of typical powers of human kind, playing a crucial role in language acquisition and knowledge that we know through Chomsky's theories on Universal Grammar which "*may be considered as a theory of innate mechanisms, a background biological matrix providing a picture within which language is developed*" "*the system of principles, conditions, rules that are […] the essence of human language"*(1979), there was no functional magnetic resonance. However, we now know exactly the links between a brain area and a function, and it is possible to "photograph" the neural paths of thoughts.

As functional magnetic resonance enables us to see the confirmation – later – of the biological matrix of the Generative Grammar and Universal Grammar principles, conceptual maps are the most effective scientific tool to identify language acquisition processes, its conceptual development, and the instrumental abilities that ensure the comprehension of written texts for the whole life.
Bühler(1934) and later Piaget acknowledge that the human language corresponds to three main living functions: communication of primary needs-desires (*expressive*), protection against dangers-calling (*signalling*), need for words as the tool to describe, i.e. communicate the thought (*representative*).
These are exactly the same functions that can be identified in the formation of written *words*, which is the intentional result of the combination of sound, sign and meaning. The same occurs in the formulation of a map where symbols play an expressive, signalling and representative role.

4.1 Previous maps and maps immediately after the acquisition of writing skills: age 6 years.

Images show some crucial steps of the acquisition of composition rules for conceptual maps, together with the acquisition of writing to the organization of actual knowledge domains, but they are also the demonstration of what may be defined as spontaneous hypertextual writing, and how children can, absolutely naturally, start using a sophisticated writing tool, such as CmapTools.

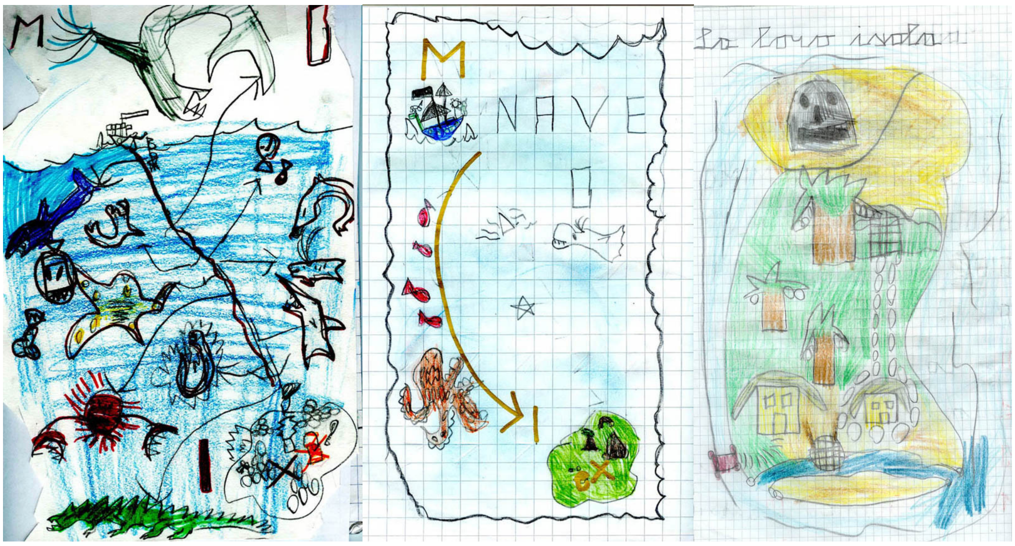
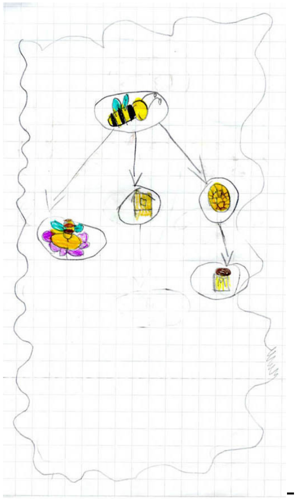


Fig.: **Map of Treasure Island** - Luigi, 6 years

The first drawing shows a Map of the Treasure Island.
The boy, Luigi, is 6 years old. During the first days of school, he does not know how to write all graphemes and he only uses two graphemes: M for map and O for gold ("oro" in Italian). Links and direction arrows appear; the path of the pirate ship, up to the island, is full of adventures (one image – one concept).
The second drawing, made after a few days, shows a full written word - NAVE (ship in Italian) – and the grapheme O for gold.
Once again, a direction line with an arrow connecting the ship with the island.
The third drawing, made a few weeks after the first two, shows a complete phrase: their island (of the pirates).
The following shows how from the map – an example of an organized narration in spite of the lack of writing abilities – there is a transition to writing of two concept words: MAP and hive; in this case, the link between the two concepts coincide with the flying bee. Finally, there is the transition to a first form of text: BEE LIVES IN THE HONEYCOMB AND THE HONEYCOMB IS IN THE HIVE.



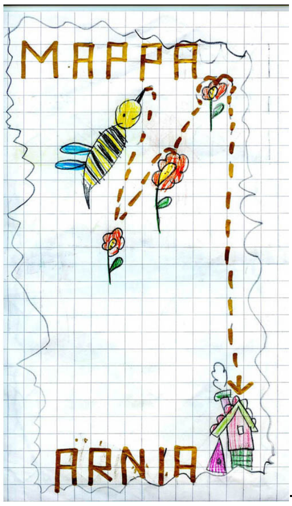


Fig.: **Conceptual map "bee"** Fig.: M**ap "hive"** Fig.: **"Bee lives in the honeycomb and the honeycomb is in the hive"**

It is possible to notice how words progressively take a full conceptual value and become knowledge units organized according to precise rules, units of meaning, which are useful to understand, reformulate and tell experiences and knowledge.

5 Conceptual maps: the story board to "sail" in the text

From a viewpoint of educational use, one of the purposes of map construction is to show the opportunity of creating relationships between concepts and realize our mental constructions.
The combination of a graphic-symbolic code with some words having a nodal signalling function (for example, the name of a town or a river) creates an effective communication within a very short time, as compared with the time required for a text describing the same information in a syntactically appropriate way. A map uses a system of signs, enabling the so-called cognitive reading. It is based on the immediate conceptual transposition of some information, which becomes the subject of interactions and correlations when they undergo our personal interpretative reading. Just think of which and how many ways we have to read a road map, a geographical map, or a star map… A map usually offers an empathic, extensible and focusable reading. There may be several and various reading levels: from immediately utilitarian levels to others starting from concrete data and stimulating our mind, so that a name or a line becomes associations of ideas, recalling of memories, sensations, desires…
It is not sufficient to ask children to create maps. To ensure this occurs with full knowledge, first we need to provide them with criteria clearly and certainly showing the operations to carry out and the related conditions, to determine their use and set the viewpoints from which maps may be considered.
The first useful indication is that maps are obviously and mostly used to be the borders of our own knowledge domains (usually treasure maps are very personal), to logically and consequentially clarify complex reasoning (very helpful to find mysterious and unknown islands), organize a story (I can tell all what I know about bees, even if I do not know how to write). Finally, they enable teachers to organize their lessons, starting from actual knowledge and curiosity of students.
Choosing to use the word MAP as a linguistic unit to learn the grapheme M, not only means giving this skill but also establishing a link between an unconscious and innate narration mode (spontaneous hypertextual) and a conscious mode: the formulation of maps whose purpose is telling a story (hypertextuality as a non-sequential organization).
As children learn that a word cannot be formed, if signs do not observe the rules of composition, also the map, a real graphical representation of thought, uses an expression code: *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.*

Fig.:**Map “LUMACONE”**

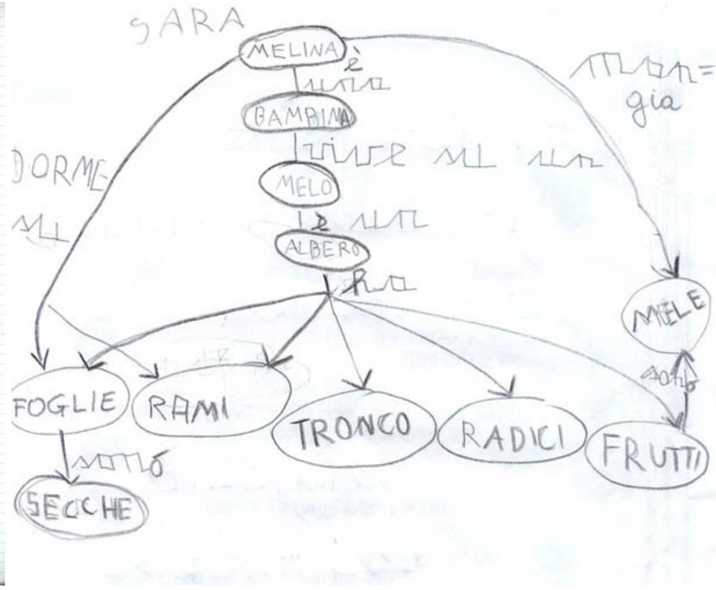


Fig.: **Map “MELINA”**

These two maps were formulated some time one after the other. These are examples to start understanding the structure of a text, and the formulation of maps is aimed at organizing verbal telling. Obviously, the transition to written text of a summary is almost simultaneous. Simultaneously, school children start using video-writing and c-maps. At the computer, they carry out activities, which strengthen and are complementary, and the instrumental abilities of learning how to read and write are strengthened. Complex abilities are acquired very early, as compared with the standard. Precociousness is not the main advantage; reading and writing map to tell stories, children are involved in both multidimensionality and unidimensionality of a text.
The map No. 1 was formulated at the beginning, when the child is starting to read and compose the first written words. There is only one word only: LUMACONE (snail), which is the name of the main character of the story, and drawings illustrating the narration sequences. The second map, “MELINA”, shows how writing skills have developed (words written with different characters appear, which are used by the child not in a casual way: concept-words with block capital letters, within their node, link-words in small italic). Lines and arrows correctly tell the story.
Children understand that maps, like all forms of communication, need shared rules, “rituals” or “signs”, which allow their reading.
The connections represented not only by lines and arrows but also link-words become very important to “read” the map. Children are able almost immediately to operate a clear distinction between concept-words and link-words; instinctively, they understand the function of syntactic and semantic rules, which control the formation of a phrase.

5.1 Acquisition of narration skills through conceptual maps: age 8-9 years

The graphical representation of a *conceptual map* is a full narration.
Usually, after all school children have had the opportunity to read their own map to the other children, synthesis is facilitated through the formulation of a shared map, at the blackboard, then children are invited to read it loudly. At that point, it becomes evident that, although there is only one map, the ways stories are told vary, according to the “path” selected to illustrate them (concept of hypertextuality of the narration path).
The transition from oral character to writing (also through very complex reasoning) is facilitated and children use, also when they are not explicitly requested, conceptual maps as tools to organize the structure of discourse. Learning how to organize their own thoughts is one of the most difficult and challenging activities children have to face.
Very often, these difficulties add up and become insuperable obstacles, organization difficulties, and children realize they have syntactic and grammar difficulties. The result can only be that these children are afraid of writing or speaking, especially in the presence of traditional teaching methodologies, based on the repetition and evaluation tests. The increasingly expert use of computer provides clear advantages for the acquisition of knowledge and skills: critical abilities are activated for the selection, and learning keeps and strengthens play and curiosity characteristics: “surfing” through the Internet is much more exciting than glancing through an Encyclopaedia…

These maps are note sheets. These are maps illustrating various subjects: history, Italian grammar and literature. They show how children, when they appropriate a tool they feel useful and facilitating in relation to their needs, they use it in an autonomous and systematic way. They only need one sheet, one pencil and some colour pens.

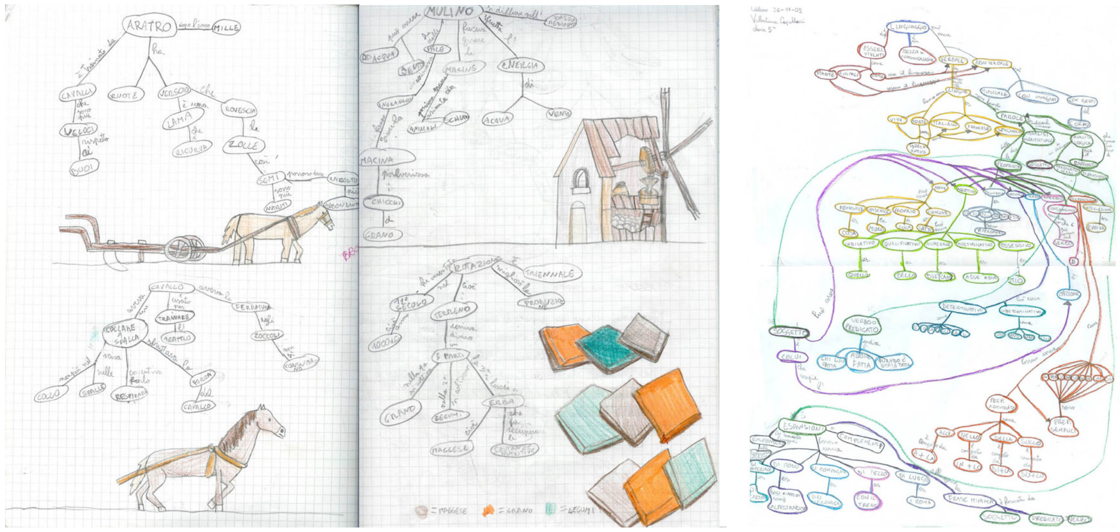


Fig. They only need one sheet, one pencil and some colour pens…

5.2 Personal organization of knowledge domains; use of CmapTools for hypertextual narrations (the maps related to interaction are part of a collaborative hypertextual work produced by the children of the last elementary school year in June 2003): age 10.11 years.

Autonomously, when they wish to communicate the result of their work, children use the CmapTools software, work on Local (something like a personal blackboard/portfolio), and upload it into Public, and then, through the servers provided by the IHMC for free, they have the opportunity to link concepts with web pages, and put their work directly on the Internet, to make it available to anybody.

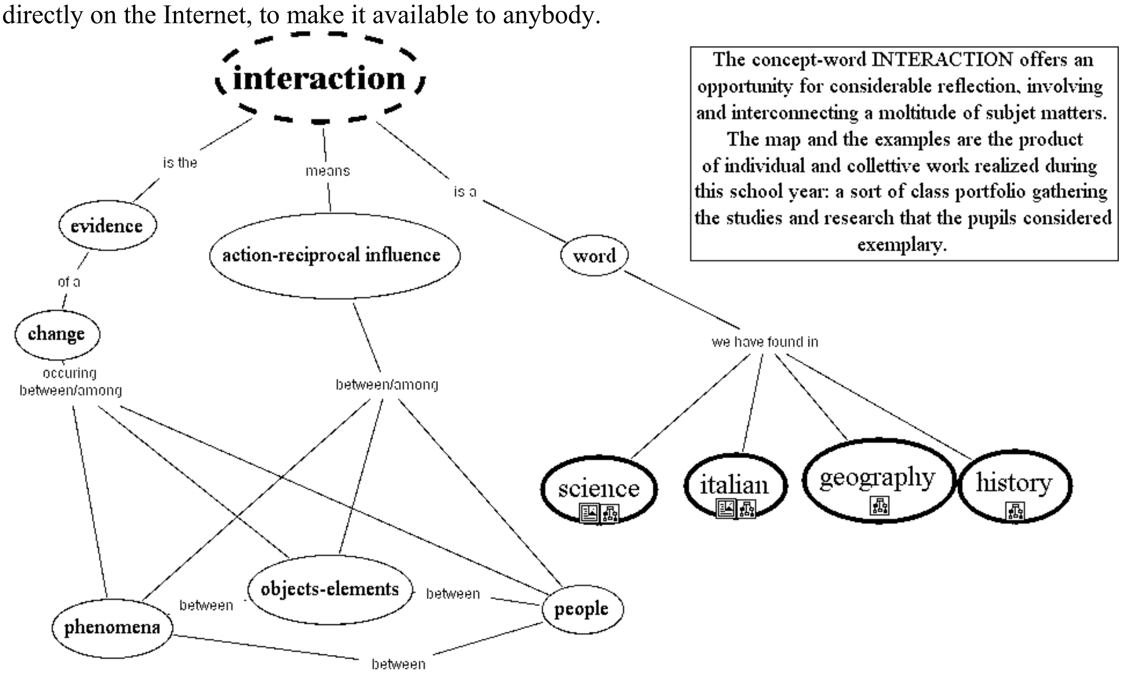


Fig. Home page of the hypertext “Interaction”, designed by the students of the 5th year of the Elementary School “Piansevero”, Urbino, Italy, published on the web site www.icvolponi.it

As the conclusion of an entire process, children (10 years old) have produced a complex hypertextual work, starting from word interaction, available on the site www.icvolponi.it

To document the word concept interaction, they have created connections, which start from the main map and illustrate the meaning in the various contexts. This is the example of how children, when they are ten years old, are able to design and develop a class cooperation work; they are able to organize their work into research subgroups; they make the materials used and produced transdisciplinary; they are able to use different languages at the same time (visual, sound, written languages); they are interactive both as readers and writers; they are able to make available to all the best (according to the judgement of every child) they have personally done with a collaborative spirit, for other hypothetical surfers on cybernetic spaces.

6 Summary

Writing, considering writing as the ability controlling the creation of signs, shows all its complexity in children (4-12 years), expression of sequential and linear thought, but also process and reticular thought.
In this context, even for children who are 6 years old, **CmapTools** was a *writing system* In practice, it works like a narration system, which ensures a complex communication, using several linguistic codes simultaneously.

7 Acknowledgements

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TWO-LAYERED APPROACH TO KNOWLEDGE REPRESENTATION USING CONCEPTUAL MAPS AND DESCRIPTION LOGICS

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Abstract. The knowledge adquisition phase in Knowledge-based systems is still an important bottleneck. Case-Based Reasoning is a paradigm to build knowledge based systems, where past stereotypical experiences are used as the main source of knowledge to solve current problems. We use a knowledge intensive approach to CBR where the involved general knowledge is formalized usign Description Logics (DLs). Our experience has taught us that DLs are too complex to be understood by domain users. We observed that, because this complexity, they try to avoid the use of the system. We developed a methodology that includes several aspects in order to break this blockage. One aspect is the use of a two-layered knowledge representation: a formal layer with DLs and a graphical layer based on CMAPS. We centered our work with CMAPS in the first stage of the knowledge engineering cycle, the conceptualization phase.

1 Introduction

The knowledge adquisition (KA) phase in knowledge-based systems is still an important bottleneck. Case-Based Reasoning (CBR) is a well known paradigm where past stereotypical experiences are used to solve current problems. This way the typical KA burden is reduced. The typical KA phase includes the conceptualization and formalization stages in the knowledge engineering cycle. It has been several approaches to ease the bottleneck. One of these approaches that has been successful is the graphical representation, such as conceptual maps (CMAPS). This type of representation is natural for the users. They have a similar kind of conceptual network to represent their knowledge in their minds.

There are other works that use CMAPS with CBR. One of the most relevant is described in (Leake&Wilson 2001). They have developed specific tools for aerospace design and stablished a framework for interactive case-based design support systems. They use CMAPS as the knowledge representation language for CBR. They have developed CBR tools specifically for this reprentation language.

On the contrary, our Knowledge Intensive CBR (KI-CBR) framework (Díaz-Agudo&González-Calero 2001; Díaz-Agudo 2002) is independent of the domain and it maybe applied to design or to any other task. The "knowledge intensive" qualifier is used when the specific knowledge described in the cases is complemented with an ontology containing general knowledge about the domain.

We[1] integrate this domain ontology with another ontology, called CBROnto, that has the knowledge about CBR itself, i.e.: case structure and the CBR processes (Problem Solving Methods that are generic and reusable) (Díaz-Agudo&González-Calero 2002). These methods include mainly similarity assessment for case retrieval and adaptation. Our KI-CBR system uses Description Logics (DLs) as the formalization language of all the knowledge, taking advantage of the charateristics of DLs for the reasoning tasks. In particular we use OWL (Bechhofer *et al.* 2004), a new standard that has recently reached a high relevance. The choice of OWL as representation language provides the additional advantage, that it is designed to work with inference engines like RACER (Haarslev & Möller 2003).

DLs are complex to be understood by domain users. We observed that, because this complexity, they try to avoid the use of the system. We developed a methodology that includes several aspects in order to break this blockage. One aspect is the use of a graphical layer, such as CMAPS. We centered our work with CMAPS in the first stage of the knowledge engineering cycle, the conceptualization phase.

There are other related works that uses two representation languages. One of these works is the effort of the RKF[2] (*Rapid Knowledge Formation*) development team, where they propose to develop a suite of tools, providing a framework to display and record the content of an evolving Knowledge Base. One of these tools is

[1] Supported by the Spanish Committee of Science & Technology (TIC2002-01961)
[2] http://www.rl.af.mil/tech/programs/rkf/

the MILK prototype. It implements a CMAPS version that communicates with Shaken, a Knowledge server developed by SRI International. MILK retrieves models from the server to be rendered as conceptual maps or verify operations that the users may perform on the models. This approach uses two different representations as ours: CMAPS and the Knowledge Server language. In our approach we keep the two languages acting as two different layers, the conceptualization and the formalization layer. Both are integrated in the methodology and the KI-CBR system.

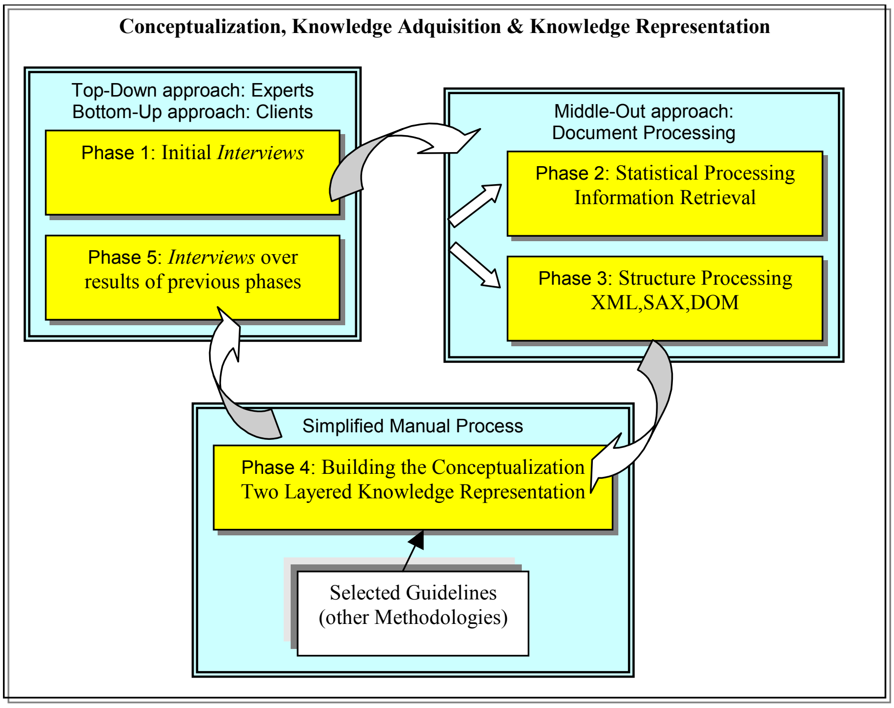


Fig. 1: Lightweight Ontology Methodology summary: Refinement Cycle

This article describes a two layered knowledge representation enbedded in a methodology to build lightweight ontologies. We have applied it in a project for a test site with good results. In order to understand the representation and its motivation we first describe briefly the methodology. Section 3 describes the first step of knowledge creation, i.e., how the domain ontology is acquired and represented using CMAPS. Section 4 introduces the basics of DLs as a knowledge representation technique, and Section 5 explains the second step of knowledge creation, i.e. how DLs are used to formalize the domain ontology. Section 6 deals with the transformation from one knowledge layer, the CMAP layer, into the other, the DLs layer. In Section 7 we describe shortly the test site, Golden Soft, a software producer for managent, and the results of a test experiment and Section 8 concludes the paper.

2 The methodology to build lightweight ontologies

To make the ontology of the KI-CBR system we reviewed, in (Gómez-Gauchía et al. 2004 a), some of the most representative methodologies to build ontologies, and we identified good guidelines that may be applied in the adequate phase of the proposed methodology, as it is shown in Fig. 1. The current methodologies to build ontologies follow a wide range of theories, approaches and scopes of their application. After doing the survey of methodologies and starting the conceptualization phase, we found several problems applying them:

1. The lack of understanding of the domain terms and the lack of experts.
2. The need to facilitate the ontology definition, using a formal representation language, by domain experts that are not computer experts. In this article we call them users.
3. The need to structure the whole process of guidelines, tasks and support materials.

To solve them we, as knowledge engineers, use theoretical paradigms already tested in other areas of research. We propose the following solutions to face up these problems:

- To obtain relevant concepts by processing written sources of knowledge, used as a guide for the next phases. We use Information Retrieval and Document Structure processing techniques.

- To support human communication through conceptual structures. We propose representing knowledge by means of two layers: a user layer with an easy graphical language, CMAPs and an internal layer with a formal representation language, Description Logics.
- To build up the ontology in an incremental manner. We define a refinement cycle. It is based on the three main conceptual strategies, top-down, bottom-up and middle-out. They are applied in different phases of the cycle, including a final phase with a manual task by the user.

In (Gómez-Gauchía et al 2004 a) we discuss the first stages of the knowledge engineering approach, i.e. the conceptualization of the knowledge acquisition and the knowledge representation of a lightweight ontology. We have defined a pragmatic methodology as a complement to other classical methodologies. The methodology, shown in Fig. 1, has three main tasks, which group five phases of the cycle. These tasks are repeated in the refinement cycle until all the participants reach a consensus of the ontology semantics. The tasks are based on the source of information and its treatment:

1. *Interviews*, with the clients in a bottom-up style and with the experts in a top-down style. It includes phase one, the initial conceptualization, and phase five, the refinement of the ontology obtained in previous phases.
2. *Document Processing* of the written documentation to extract the most relevant terms. This is the middle-out strategy. Depending on the nature of documents, a statistical processing, phase two, or a document structure processing, phase three, is applied.
3. *Simplified Manual Process* to build the ontology in a two-layered representation, that takes, as basis the relevant concepts obtained in the previous tasks. This is phase four. The selected guidelines of the studied methodologies in the survey are applied in this task. The user only works with the informal graphical representation, leaving the formal layer internal to be used by the KI-CBR system.

The phase 4 is where the two-layered representation is applied. The solution was to define an incremental knowledge process with two cycling steps:

- *Conceptualization:* the user describes a piece of knowledge in a graphical language using CMAPS.
- *Formalization:* the system tries to automatically formalize the new portion of knowledge in a paradigm, such as DLs, that allows performing the verification and reasoning tasks that the KI-CBR system needed. This process is described in section 6 of this article.

The one-layered representation follows the *meaning triangle* (Ogden & Richards 1946). It makes a distinction between the symbol, the concept and the object, as depicted in Fig. 2a. For our particular application, the external symbol is the term or image that is drawn in the CMAP; the concept, inside the human agent, is what is named by the term; and the object, the thing in the real world, referred to by the concept. The theory behind the two-layered representation is the inclusion of the forth element, the *internal formal universe* (Hartley & Barnden 1997), into the meaning triangle. This gives the formal semantics needed to be able to reason with the meaning model drawn in Fig. 2b.

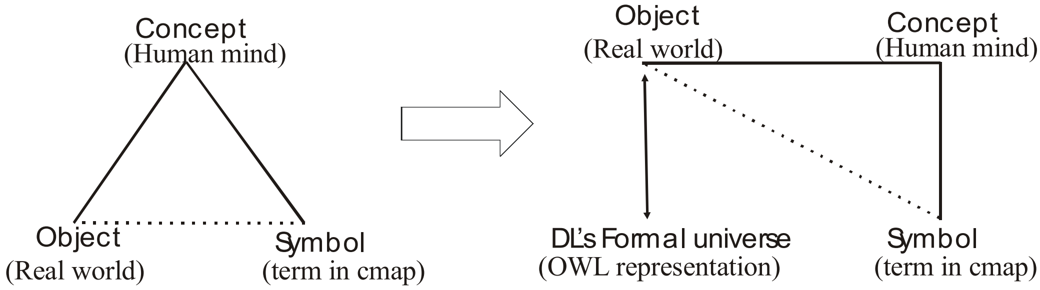


Fig. 2 a) The Meaning Triangle b) Formal Semantics included in the Meaning Triangle

3 The representation of our ontologies with Conceptual maps

As we have described, in our project we define and integrate two ontologies. To do it, we use the CmapTools system made by the Institute for Human and Machine Cognition. A small portion of them is depicted in Fig. 3:

- CBROnto (left) supplies the framework to represent the elements needed to deal with the CBR paradigm. It has around 200 terms, between concepts and relations.
- Domain ontology to represent the concepts of the application domain, the managment of companies in our project. It has few hundreds elements as well.

From the user point of view the main difficulty to deal with them is the so call *growth problem*: to be able to have a perspective of the relative location of an element in relation with the whole ontology. It is difficult even with a graphical editor, such as Protege that uses lists of topics in a hierarchy.

The main problem associated with Protege is that its *tree-like* representation of graphs does not allow a clear visualization of the structure of the knowledge. It is serious in our application because we use intensively multiple inheritance specially during the integration between the domain ontology and CBROnto (Díaz-Agudo&González-Calero 2002).

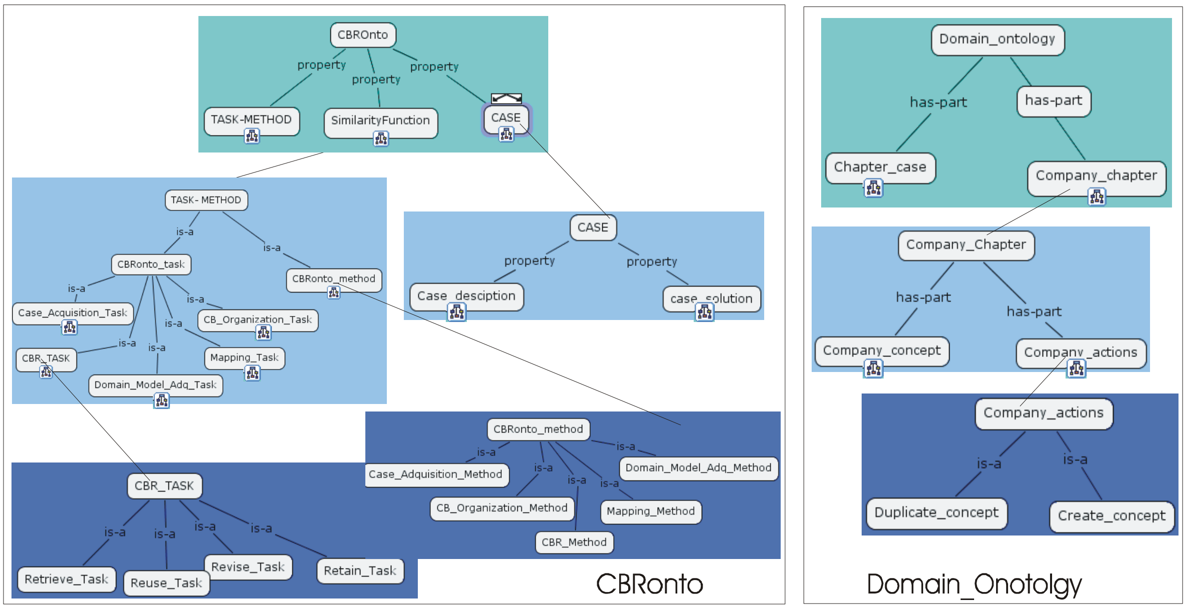


Fig 3. Ontologies of the Methodology applied to a KI-CBR system of Help-Desk

To deal with the problem in this phase, we facilitate the visual comprehension using CMAPS. We obtained possitive results using some restrictions in these maps:

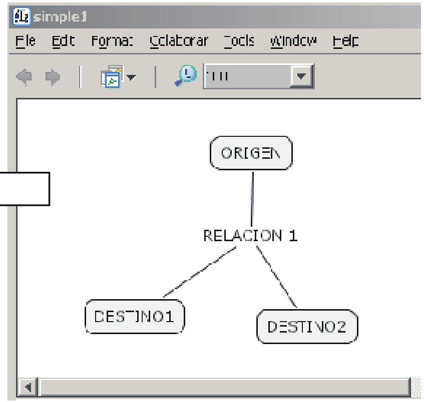
- To create many small CMAPS with few concepts and relations each.
- To organize them in an ortogonal manner:
  - horizontally by levels of abstraction
  - vertically by subareas of the ontology.
- This is done by a code based on colours.

A different but important goal is that we must be able to formalize them into a DLs language. To obtain this we check the consintency of the map against its formal representation as we see in the next section.
The advantages of CMAPS representation are mainly congnitive. The users of the ontologies understand easily the ontology as a whole and they follow the relative position of each concept and relation in the whole ontology. The CMAPS graphical represention is a familiar format for non-thecnical users. A specific advantage of the CmapTools is that the internal representation languge is XTM, a small portion is in the Fig 4. The XTM is part of the ISO/IEC 13250 Topic Maps standard that enables to describe and navigate information objects (Biezunski & Newcomb 2001). The main disadvantage is that CMAPS don´t allow a formalization of the knowledge in order to check inconsinstencies and to reason with it. This is the motivator to use the DLs language.

4 The representation of our ontologies in Description Logics

DLs are considered one of the most important knowledge representation formalism unifying and giving a logical basis to the well known traditions of Frame-based systems, Semantic Networks, Object-Oriented

```
<topicMap id="1082994524453_1445937377_486"
 xmlns="http://www.topicmaps.org/xtm/1.0/" …. >
  <topic id="1082994122796_538001187_441">
   <instanceOf>
    <subjectIndicatorRef ….. xlink:href="http://cmap.coginst.uwf.edu/#concept"/>
   </instanceOf>
   <baseName>    <baseNameString><![CDATA[DESTINO1]]></baseNameString>
    </baseName>
  </topic>
   …                                    other 'concept' topic
   <baseName>    <baseNameString><![CDATA[DESTINO2]]></baseNameString>
   …                                    other 'concept' topic
   <baseName>    <baseNameString><![CDATA[ORIGEN]]></baseNameString>
   …
                 xlink:href="http://cmap.coginst.uwf.edu/#linkingPhrase"/>
   …                                    a 'linkingPhrase' topic
             <baseNameString><![CDATA[RELACION ]]></baseNameString>
   …
  <association id="assoc_1082994122812_680129440_444">
   …
                         xlink:href="http://cmap.coginst.uwf.edu/#incoming"/>
   …                                          → this number is ORIGEN
   <topicRef xlink:type="simple" xlink:href="#1082994112359_1142850275_427"/>
   …
     <subjectIndicatorRef xlink:type="simple"
                 xlink:href="http://cmap.coginst.uwf.edu/#outgoing"/>
   …                                          → this number is DESTINO 1
   <topicRef xlink:type="simple" xlink:href="#1082994122796_538001187_441"/>
   …
                         xlink:href="http://cmap.coginst.uwf.edu/#outgoing"/>
   …                                          → this number is DESTINO 2
  <topicRef xlink:type="simple" xlink:href="#1082994142328_1528135851_471"/>
```



Transformation into OWL format

Fig 4. A conceptual map: graphical representation in CmapTools and in XTM format

representations, Semantic data models, and Type systems. They are characterized by its expressiveness and clearly defined semantics. DLs capture the meaning of the data by concentrating on entities, which are grouped into classes or concepts. The entities are associated by relationships. This intuition is shared by formalisms such as semantic data models, semantic networks or frame systems. More important than the DLs representational characteristics are its reasoning mechanisms. The most important characteristic is the checking of inconsistencies and the organization of the concepts on a taxonomy that the system automatically builds from the concept definitions. This is possible because of the clear and precise semantic of concept definitions that avoid the user to put the concepts in the correct place of the hierarchy. This task is done manually in other systems, such as frame systems, which provide inheritance but not classification.

DL reasoning mechanisms are based on three main functions. The first one is subsumption, to determine whether a description -concept or relation- is more general than another. The second one is instance recognition, to determine the concepts that an individual satisfies and the relations that a tuple of individuals satisfies. The third one is contradiction detection, both for descriptions and assertions about individuals. Subsumption supports classification, i.e., the ability of automatically classifying a new description within a semi-lattice of previously classified descriptions. Instance recognition supports completion, i.e., the ability of drawing logical consequences of assertions about individuals, based on those descriptions they are recognized as instances of.

DLs are first-order logic predicate calculus with ideas from semantic networks that allow hierarchical representation of classes and instantiations of terms and their relationships, called TBox, the terminological box, and assertions over them, called ABox, the assertional box. To build the lightweight ontology is only necessary the TBox.

Regarding KI CBR, our main contribution is the definition of a domain-independent architecture to help in the integration of ontologies for CBR applications. The core of this architecture is CBROnto, an ontology incorporating the common CBR terminology that is used to guide the domain ontologies integration. It is done in a subsequent phase, after the domain modelling phase: the CBR application designer relates the specific domain knowledge with the CBROnto terms. This integration between the CBR terminology and the domain knowledge, allows reusing generic problem solving methods (PSMs) that are defined using the CBR terminology. DLs classification allows that PSMs have access and reason with the domain terms that are classified below the CBR terms.

We use DLs reasoning mechanisms and deductive inferences based on subsumption and instance recognition. Subsumption determines if a term is or not more general than another, and instance recognition finds all the concepts that an individual satisfies. Furthermore, completion mechanisms perform logical consequences like inheritance, combination of restrictions, restriction propagation, contradiction detection, and incoherent term detection. These mechanisms will be used during the ontology integration, the case representation and, in general, as the base for all the CBR processes.

The description of the intensive use of the DLs reasoning mechanisms to help the CBR processes is out of the scoper of this paper. We refer the interested reader to (Díaz-Agudo 2002).We formalize our ontologies, Domain and CBROnto, using OWL as internal representation. For the reasoning tasks we loaded it into RACER

```
<owl:Class rdf:ID="DESTINO1"/>
<owl:Class rdf:ID="ORIGEN1">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:someValuesFrom>
        <owl:Class rdf:ID="DESTINO2"/>
      </owl:someValuesFrom>
      <owl:onProperty>
        <owl:ObjectProperty rdf:ID="RELACION1"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:someValuesFrom rdf:resource="#DESTINO1"/>
      <owl:onProperty rdf:resource="#RELACION1"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

Fig. 5. The example transformed into OWL

(Haarslev & Möller 2003). RACER is a DL reasoner that reads OWL.

5 The transformation of our ontologies from CMAPS to Description Logics

The transformation from CMAPS to DLs takes into account the different expressiveness of both formats for our specific problem. We process only the elements that affect to the representation in our system. We describe the process using a simple example. The transformation process is associated to the updating process, that maybe online or offline. To allow the inclusion of existing CMAPS, there is an offline load process of the map into the DL layer. The online process is when the user modifies the ontologies with a graphical interface, like the CMAPS program.

5.1 The offline process: loading existing conceptual maps

We use as basis two facts: CmapTools is able to export, as in Fig.4, the map to the XTM language and the DLs language that uses the reasoning engine is OWL. Since both languages are XML based we use a parser to perform the load process. We use the sort example in CMAPS and XTM of Fig. 4 and its equivalent in OWL of Fig. 5 to describe the relevant elements that are needed for the transformation. We don't need the graphical information of the XTM map; we only use its conceptual elements:

- The *topic* tag that defines the labels and their role e.g.: `<topic id="10829922796_538001187_441">`. They have a unique identifier used to refer to them later in the map. They are instances of two classes:
  - o *Concept,* that refers to the concept itself.
  - o *LinkingPhrase,* that defines the relationship among concepts.
- The *association* tag that defines the specific relations of a *linkingPhrase* with the *concepts*. The id is the same one of the *linkingPhrase*, e.g.: `<association id="assoc_12_6809440_444">`. It has the role specification of the concepts in the relation to define the direction of the map:
  - o *Incoming* concepts are the origin
  - o *Outgoing* concepts are the target

We generate the OWL formalization using the same structure that uses the RACER reasoning engine. Following the example in the Fig. 4 and 5 we have:

- A relation in CMAP, i.e.: a *LinkingPhrase* topic, is generated as a property in OWL:

  e.g. `<owl:ObjectProperty rdf:ID="RELACION1"/>`

- A concept in CMAP, i.e.: a *concept* topic, is generated as a class in OWL

  e.g. `<owl:Class rdf:ID="ORIGEN1">`
- A relation in CMAP, i.e.: an *association* tag, is generated in OWL following this process:
  - To connect a relation with the concepts that are part of it, an anonymous class is created with `<rdfs:subClassOf>` inside the origin concept. This way the subclass inherits from the concept. The declaration of the connection is made with a restriction `<owl:Restriction>` with two elements: the target concept, that is a class e.g. `<owl:Class rdf:ID="DESTINO2"/>` and the relation, that is a property, e.g. `<owl:onProperty rdf:resource="#RELACION1"/>`.
  - A conflict appeared because RACER allows unary and binary predicates, and, on the contrary, CMAPS allow relations many to many. This is solved by the creation of one anonymous class for each pair of concepts related. In the Fig. 5 shows the complete example in OWL format.

5.2 Online updates

The are two types of online updates:

- The *terminological updates* with the Tbox of the DLs. The user with the graphical interface makes them in the CMAP layer. In this layer there is not distinction between primitive and defined concepts.
- The *assertive updates* with the Abox. These are restrictions over the *instances*, the cases in the Case Base of our project. This is made in the DLs layer because there is no representation of instances in CMAPS. This is done with an OWL editor, such as Protege 2.0.

In this manner, the transformation problem is centered in the *terminological updates*. These are the steps we take:

1. The user introduces a change in a concept or in a relation (CMAPS layer)
2. The system checks with the DLs reasoning engine (RACER in `*auto-realize*` mode)
3. If it is inconsistent with the current ontology: it displays a message
4. If it is consistent: it includes the modification into the DLs layer
5. The cycle 1 to 4 continues until all the updates are performed.

6 Results

As a test site, we are developing a project for a software company. The company is called GoldenSoft in Spain. It needed a computer support for a very demanding human work of the Department of Client Attention, or, the so-called, Help-Desk. GoldenSoft is one of the main local software companies developing software for the management of small and medium size companies. It sells five complex integrated applications for invoicing, accounting, payroll, teller machines and taxes. The Help-Desk supports the phone calls with questions about these applications. One of the keys of its success is this Help-Desk department with ten technicians that are trained during a year before they are ready to answer calls. They attend two hundred calls a day about complex problems of several kind of topics, mainly program errors, application use, legal or computer user related issues. Some of these questions take even hours to be solved.

In (Gómez-Gauchía et al. 2004 b) we have described the knowledge elicitation phase associated to this project. Although we have tried to automate the process, the experts still has two remaining hard duties:

1. Revise and refine general knowledge about the domain that is automatically extracted from the company documentation.
2. Integrate the domain terminology within the CBROnto terminology in order to allow the reusable methods included in CBROnto can work properly with the domain terminology.

We distinguish between two different stages of the test. During the first one we convince the experts of using Protégé, a DLs graphical editor to help them in the domain knowledge refinement and integration within CBROnto. During the second one we provide with a CMAP based interface to help their tasks. We have performed two polling processes applied to 10 domain experts. We have compared the opinion polls results and they clearly indicate that CMAPS facilitate the visual comprehension of the model. An informal productivity test has been performed showing a reasonable improvement, but a more formal test is needed.

7 Conclusions and further work

Ontology modeling deals with the question on how to describe in a declarative and reusable way the domain information of an application, its relevant vocabulary, and how to constrain the use the data, by understanding what can be drawn from it. In this paper we have described a two layered approach embedded in a methodology to ontology modeling. The first layer is based on CMAPS to facilitate the visual comprehension of the model and help the experts to define medium to large number of concepts and relations. The second layer is based on DLs. In particular, DLs well founded semantics facilitate the analysis of knowledge, avoidance of incompleteness, inconsistencies and redundant knowledge. We tested this approach in a project with aceptable results.

As a further work we plan to give a software support to the methodology in order to manage the complete cycle of refinenment. It includes authoring, collaboration, validation and versioning tools. Also it will be carry out formal tests with metric polls to evaluate the improvements.

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VALORACIÓN CUANTITATIVA PARA EVALUAR MAPAS CONCEPTUALES

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Resumen. Los mapas conceptuales son diagramas que indican las relaciones entre los conceptos y pueden verse como diagramas jerárquicos que procuran reflejar la organización conceptual de una disciplina, con estos se han desarrollado diferentes líneas de investigación, aunque en general se acepta el hecho de que constituyen un recurso potencial en la práctica docente. Existen diversas formas de evaluar el aprendizaje significativo mediante la utilización de mapas conceptuales, en este trabajo se presenta la metodología del análisis bidimensional o Prueba de Asociación Olmstead-Tukey como una herramienta diagnóstica y de evaluación en el manejo de conceptos de tipo grupal. Se aplicó a diferentes grupos del bachillerato de la UNAM (México) considerando el sector educativo del cual egresaron. El análisis se centró en diferentes conceptos relacionados con Biología, encontrándose asociaciones con la Prueba Olmstead-Tukey y corroboradas por la prueba estadística de ji cuadrada. La aplicación de esta prueba en otros grupos permitirá verificar la confiabilidad de la prueba, para en un futuro diseñar un software que permita facilitar la interpretación de mapas conceptuales de alumnos, en grupos numerosos.

1 Introducción

Los mapas conceptuales son diagramas que indican las relaciones entre los conceptos y pueden verse como diagramas jerárquicos que procuran reflejar la organización conceptual de una disciplina, con estos se han desarrollado diferentes líneas de investigación, aunque en general se acepta el hecho de que constituyen un recurso potencial en la práctica docente (Moreira, 1988; Al-kunfield y Wandersee, 1990; Novak, 1990; Shavelson, 1993)

Wallace y Mintzes (1990) realizaron un breve análisis de las tendencias existentes para el uso de mapas conceptuales en la década de los 80 y señalan que una parte de las investigaciones se han canalizado para utilizarlos como elementos heurísticos en los alumnos y facilitar el aprendizaje de otros campos del conocimiento. Así mismo, añaden que otro tipo de estudios se enfocó hacia la posibilidad de que los estudiantes puedan exteriorizar de manera gráfica los conceptos y la forma en que estos son asociados por los alumnos, para poder así establecer un punto de comunicación para la reflexión de como aprende el alumno (metaconocimiento y metaprendizaje).

Ontoria et al. (2001) señalan otras formas de aplicación de los mapas conceptuales en forma de técnicas: a) de tipo cognitivo, b) para compartir significados, c) para relacionar los conceptos de una unidad didáctica, d) para evaluar, entre otras. Para el caso de la evaluación, la consideran como "...parte integrante de todo modelo educativo que se refleja en el proceso de enseñanza-aprendizaje y, en definitiva, es una actividad primordialmente valorativa e investigadora, a través de la cual se toman decisiones que contribuyen a regular el proceso educativo." Bajo esta perspectiva la evaluación debe tener un carácter procesual y continuo.

De igual manera, Ontoria et al. (2001) mencionan a las proposiciones, la jerarquización, las relaciones cruzadas y ejemplos, como elementos que deben ser valorados para emitir un juicio cualitativo o cuantitativo (asignar puntajes) al momento de evaluar el aprendizaje significativo en los mapas conceptuales. Existen diversas formas de evaluar el aprendizaje significativo mediante la utilización de mapas conceptuales, pero una de las desventajas de trabajar con mapas es el tiempo que se invierte en su interpretación, razón por la cual se requiere de una herramienta que solucione este inconveniente. Si consideramos que en México un profesor de bachillerato tiene a su cargo grupos con más de 40 alumnos, el uso de mapas se convierte en una herramienta de difícil aplicación. El actual desarrollo de la informática ofrece una posible vía mediante la generación de un software que resolviese esta situación.

Un primer paso sería el diseño de un método para que al introducir los datos al programa, éste proporcionara resultados que permitieran al evaluador tomar las decisiones pertinentes sobre el proceso educativo. En una segunda instancia habría que valorar la eficacia de este método. Por último, el diseño y construcción del software sería la etapa final. Actualmente nos encontramos en la etapa de valoración de esta metodología, que es uno de los propósitos de asistir a esta reunión académica. La metodología es el análisis bidimensional o Prueba de Asociación Olmstead-Tukey (Zar, 1974; Sokal y Rohlf, 1985; García de León, 1988) aplicada como una herramienta diagnóstica y de evaluación en el manejo de conceptos de tipo grupal, la cual contribuye al diseño de estrategias de aprendizajes y la estructuración de planes de estudio.

2 Metodología

El plantel 2 “Erasmo Castellanos Quinto” es el único en el sistema del bachillerato de la Universidad Nacional Autónoma de México (UNAM) en el cual se imparte, además de la enseñanza media superior, el equivalente al ciclo de estudios de nivel secundaria de la Secretaria de Educación Pública (SEP) y que se denomina “Iniciación Universitaria”. Los profesores que laboran en este plantel a nivel preparatoria tienen la posibilidad de recibir egresados de diferentes sectores educativos: de la SEP, Iniciación Universitaria (UNAM) y de escuelas particulares.

Con base en este universo de egresados, se decidió utilizar los mapas conceptuales para explorar la forma en que los alumnos de dichas escuelas asocian algunas palabras importantes en el contexto del programa de Biología IV de la Escuela Nacional Preparatoria de la UNAM. Cabe señalar que los resultados que se presentan en este trabajo son de tipo diagnóstico. Este trabajo se realizó durante el ciclo escolar 1994-95 con una población de 221 alumnos que cursaron la asignatura de Biología IV de 5º año de bachillerato, de los cuales 38 fueron egresados de Iniciación Universitaria, 120 egresados de la SEP y 11 de escuelas particulares; así mismo, se trabajó con una población de 53 alumnos que cursaron el bachillerato en el “Colegio México” (escuela incorporada a la UNAM) en el mismo ciclo escolar.

La aplicación de los mapas conceptuales consistió en:

1. Explicar a los alumnos el concepto de mapas conceptuales, posteriormente se elaboraron mapas utilizando conceptos no relacionados con biología como una forma de ejercicios, (Duración: dos sesiones de 50 minutos)
2. Se elaboró una lista de 20 palabras ordenadas alfabéticamente, las cuales están relacionadas con los conceptos mínimos que debe aprender un estudiante al finalizar el curso de Biología IV. Se procuró que las palabras elegidas formaran parte de los cursos anteriores de la asignatura. Se generaron bloques de cuatro palabras correspondientes a cada una de las cinco unidades del programa de Biología IV (tabla 1).
3. En una sesión de 30 minutos, cada alumno elaboró un mapa conceptual con las palabras clave que ubicará como familiares de la lista de 20 palabras.

Unidad I: Introducción al conocimiento científico	Unidad II: Bases de la ecología	Unidad III: Evolución y diversidad	Unidad IV: Continuidad de la vida	Unidad V: El sistema vivo
Ciencia	Ciclo de la materia	Biodiversidad	Fecundación	Organelos
Conocimiento	Ecosistema	Especiación	Ácidos nucleicos	Célula
Método	F. abióticos y bióticos	Selección natural	Mitosis	Fotosíntesis
Tecnología	Flujo de energía	Adaptación	Reproducción	Respiración

Tabla 1. Conceptos para cada unidad didáctica, utilizados por los alumnos para la elaboración de mapas conceptuales. (A los alumnos se les presentaron en orden alfabético)

El análisis de los mapas conceptuales se llevó a cabo de la siguiente manera:

1. Con la información que proporcionó cada mapa, se generó una matriz de asociación (tabla 2).
2. Se cuantificaron las asociaciones de palabras entre las matrices de cada sector educativo (SEP, UNAM, Particular), elaborándose una matriz general por sector.
3. Cada bloque de cuatro palabras por unidad forma un total de 12 asociaciones esperadas, de las cuales se calcularon las frecuencias de asociación tomando como base la matriz generada por sector.
4. Se aplicó la prueba de X^2 (ji cuadrada) entre las frecuencias de asociación de los diferentes sectores (Zar, 1974).
5. Se utilizó la Prueba de asociación Olmstead –Tukey o Análisis Bidimensional (Zar, 1974; Sokal y Rohlf, 1985; García de León, 1988) para determinar: conceptos **dominantes** (mayor frecuencia de asociación y mayor número de relaciones establecidas por los alumnos); conceptos **ocasionales** (menor frecuencia de asociación y mayor número de relaciones); conceptos **constantes** (mayor frecuencia de asociación y menor número de relaciones); conceptos **raros** (menor frecuencia de asociación y menor número de relaciones).
6. Se tomó en cuenta la jerarquía de conceptos en la estructura de los mapas conceptuales, para establecer una secuencia entre los temas y determinar si siguen el orden propuesto en el programa de Biología IV.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ácidos nucleicos	1																				
Adaptación	2																				
Biodiversidad	3																				
Célula	4																				
Ciclo de la materia	5																				
Ciencia	6																				
Conocimiento	7																				
Ecosistema	8																				
Especiación	9																				
F.abióticos, bióticos	10																				
Fecundación	11																				
Flujo de energía	12																				
Fotosíntesis	13																				
Método científico	14																				
Mitosis	15																				
Organelos	16																				
Reproducción	17																				
Respiración	18																				
Selección natural	19																				
Tecnología	20																				

Tabla 2. Matriz de asociación entre los 20 conceptos del programa de Biología IV (a cada concepto le corresponde un número que se ubica hacia el lado derecho del mismo; de igual manera, los conceptos se repiten para cada columna en donde solo se indica el número que le corresponde).

3 Resultados

En la tabla 3 se muestran las frecuencias y porcentajes de asociación de las unidades por sector educativo. Cada unidad está formada por las 12 relaciones que se pueden establecer a partir de las cuatro palabras que constituyen el bloque. La prueba ji cuadrada indica que no existen diferencias significativas en la proporción de asociaciones entre cada uno de los sectores (X^2 =12.51; gl=8; p>0.05), siendo las palabras relacionadas con la primera unidad: Introducción al conocimiento científico, donde se presenta el mayor porcentaje de frecuencia de relación de conceptos (45% para los egresados de la SEP, 45% para los de Iniciación Universitaria y 42% para particular).

UNIDADES	SEP	UNAM	PARTICULAR
I	386 (46%)	146 (45%)	243 (43%)
II	77 (9%)	32 (10%)	83 (14%)
III	115 (13%)	44 (14%)	115 (20%)
IV	155 (18%)	48 (15%)	66 (11%)
V	124 (14%)	51 (16%)	67 (12%)

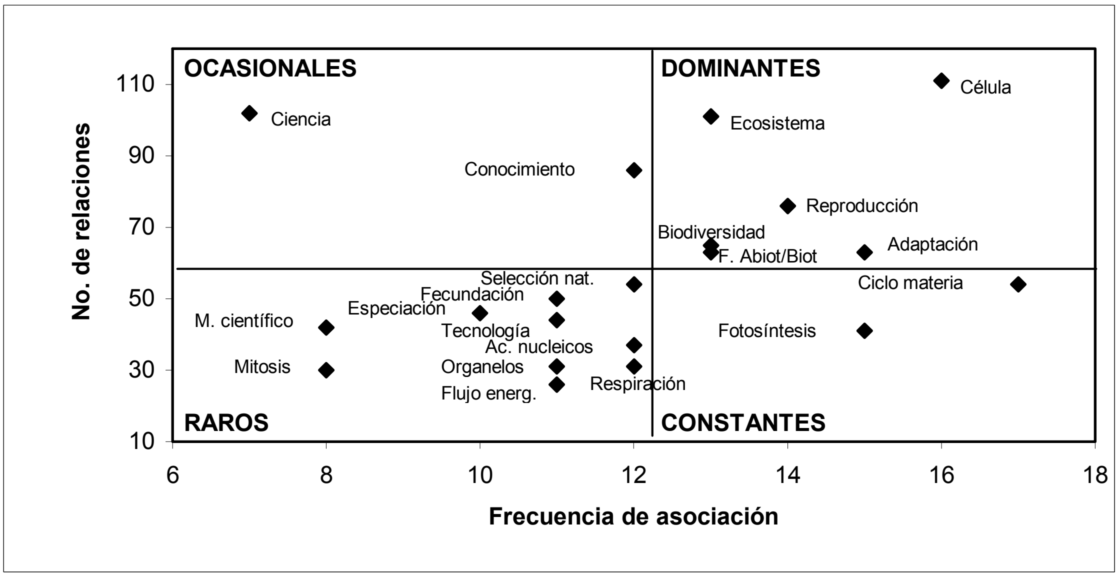
Tabla 3. Frecuencia y porcentaje de asociación de conceptos para cada unidad, y por cada sector educativo. (X^2 =12.51; gl=8; p>0.05)

La tabla 4 muestra la clasificación de los conceptos de acuerdo a la prueba de Olmstead-Tukey para cada sector educativo. Al compararlos entre sí, se observa que existen palabras comunes entre los tres sectores: a) los conceptos dominantes son célula y ecosistema; b)el único concepto constante es la palabra fotosíntesis, c) de la misma manera el único concepto ocasional es la palabra ciencia; d) conceptos raros fueron las palabras ácidos nucleicos, organelos y especiación. Otra forma de representar la frecuencia de asociación y número de relaciones de los conceptos para cada sector educativo, es mediante una gráfica que los clasifique en dominantes, constantes, ocasionales y raros, lo cual facilita el análisis. La gráfica 1 es un ejemplo que muestra estas relaciones para el caso del sector educativo particular, de la misma manera se pueden graficar para los otros sectores educativos.

Analizando el orden jerárquico de los 20 conceptos, para cada uno de los mapas conceptuales elaborados por los alumnos de los diferentes sectores, se observó que el 48% de los mapas presenta una estructura que muestra una secuencia similar a la propuesta en el programa de estudio de Biología IV con relación al orden de sus unidades temáticas (Introducción al conocimiento científico, Bases de la ecología, Evolución y diversidad, La continuidad de la vida, y El sistema vivo); el 19.7% de los mapas analizados, reflejó una secuencia siguiendo un orden de acuerdo a los niveles de organización, es decir, Introducción al conocimiento científico, El sistema vivo, La continuidad de la vida, Bases de la ecología, Evolución y diversidad; el 32.3% restante, presenta diferentes tipos de arreglo jerárquicos en la estructura de los mapas, (figura 1).

SEP			
Conceptos Dominantes	**Conceptos ocasionales**	**Conceptos constantes**	**Conceptos raros**
Célula	Ciencia	Adaptación	Tecnología
Ecosistema	Conocimiento	Fotosíntesis	Especiación
Reproducción	Biodiversidad	Fact. Bióticos, Abióticos.	Ciclo Materia
Fecundación	Método Científico	Respiración	Organelos
Selección natural		Mitosis	Ácidos nucleicos
		Flujo de energía	
Iniciación (UNAM)			
Célula	Ciencia	Fotosíntesis	Fecundación
Ecosistema	Conocimiento	Adaptación	Organelos
Tecnología	Reproducción	Ciclo materia	Flujo de energía
Biodiversidad	Método Científico		Mitosis
Selección natural			Especiación
			Respiración
			Fact. Bióticos, Abióticos.
			Ácidos nucleicos.
Particular.			
Célula	Ciencia	Ciclo materia	Selección natural
Ecosistema	Conocimiento	Fotosíntesis	Fecundación
Reproducción.			Método Científico
Biodiversidad			Especiación
Fact. Bióticos, Abióticos.			Tecnología
Adaptación			Ácidos nucleicos.
			Mitosis
			Organelos
			Flujo de energía
			Respiración

Tabla 4. Clasificación de los conceptos de Biología para cada sector educativo, utilizando la prueba de asociación Olmstead-Tukey.



Gráfica 1. Asociación de conceptos mediante la prueba Olmstead-Tukey para el sector educativo particular

4 Discusión y Conclusiones

Un primer punto de análisis, lo constituye el hecho de que los alumnos, de acuerdo con los resultados obtenidos, manejan en su estructura cognoscitiva una mayor proporción de relaciones de asociación entre los conceptos de ciencia. Probablemente la razón de esto es, el hecho de que diversas asignaturas (relacionadas o no con disciplinas científicas), también utilizan y enseñan términos relacionados con ciencia. Sin embargo habría que realizar otro tipo de estudios sobre la forma en que están aprendiendo y relacionando dicho concepto.

Lo que también sugieren estos resultados es que la propuesta del programa de Biología IV, en el sentido de que el primer bloque de conocimientos que aprenda el alumno debe estar relacionado con ciencia es adecuada, ya que es consistente con la directriz del constructivismo de que al alumno se le facilitará aprender el conocimiento si posee algunas ideas y asociaciones previas así como iniciar de lo concreto a lo abstracto.

La tabla de Olmstead- Tukey apoya la propuesta anterior, ya que la palabra ciencia es mencionada frecuentemente, pero asociada con pocos términos, por lo que el esfuerzo del docente se dirigirá hacia establecer estas relaciones que permitieran que el concepto de ciencia se ubicara de ser una palabra ocasional a una dominante.

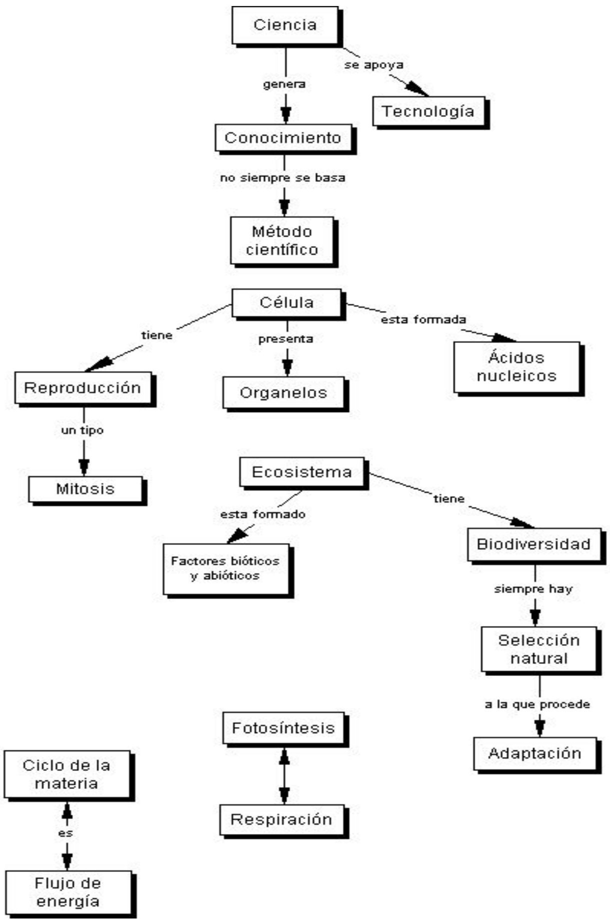


Figura 1. Ejemplo de un mapa conceptual elaborado por un alumno (Jesús, 17 años de edad, Colegio México), en donde se muestra el orden jerárquico de los conceptos

Con relación a los conceptos dominantes, que son célula y ecosistema, se plantea una disyuntiva; el programa de Biología IV sugiere que el segundo bloque de conocimientos este relacionado con Ecología. Sin embargo, de acuerdo con la tabla de Olmstead-Tukey, también existe la posibilidad de continuar con el bloque de conocimientos que este relacionados con Ecología. Sin embargo, de acuerdo con las tablas de Olmstead-Tukey, también existe la posibilidad de continuar con el bloque de conocimientos relacionado con célula, pero que en el caso del programa de Biología IV se sugiere que sea el último bloque. Con base únicamente en esta prueba, el hecho de que conceptos como organelos y ácidos nucleicos sean manejados como raros por los alumnos, sugieren que quizá sea más difícil empezar como segundo bloque con célula. La palabra fotosíntesis, que es un concepto constante, lo mismo puede ser manejada para integrar el bloque de célula que el de Ecología, aunque los alumnos lo relacionan más con este último.

Al respecto, la secuencia seguida en los mapas conceptuales que elaboraron los alumnos, también apoya el punto de vista del programa de Biología IV. Así mismo, refleja que un porcentaje importante de alumnos esta familiarizado con la secuencia de un segundo bloque de conocimientos relacionados con célula. Una conclusión definitiva requiere de una mayor evidencia cualitativa y cuantitativa.

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COMPASS: AN ADAPTIVE WEB-BASED CONCEPT MAP ASSESSMENT TOOL

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Abstract. In this paper, we present the architecture of an adaptive web-based concept map assessment tool, named COMPASS, which aims to support the assessment as well as the learning process. The presentation of the main modules of the tool focuses on the representation of the domain knowledge and the learner model, the diagnosis of the learner's knowledge and the generation of the adaptive feedback. Based on an assessment goal that the learner selects, COMPASS provides various assessment activities, which employ concept mapping tasks. The diagnosis process identifies and analyses the learner's beliefs represented on his/her map in order to perform (i) a qualitative estimation of his/her knowledge based on a categorization of the different types of errors, and (ii) a quantitative estimation of his/her knowledge level based on specific assessment criteria. Aiming to stimulate learners to reflect on their beliefs, COMPASS incorporates different informative and tutoring feedback components, in terms of delivering individualized feedback.

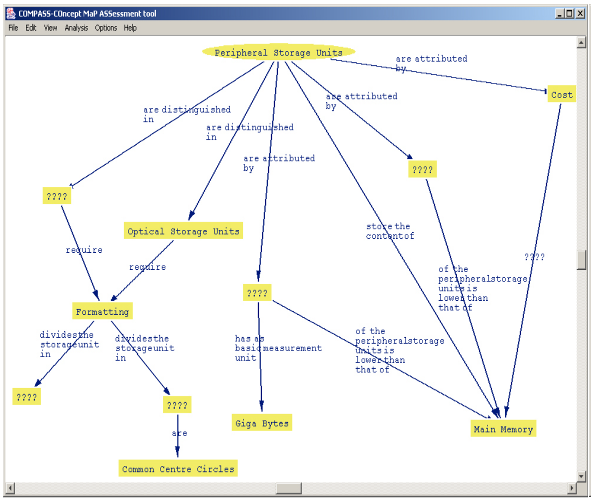
1 Introduction

Concept mapping stimulates learners to articulate and externalise their actual states of knowledge. Novak and Gowin (1984) noted that concept mapping is a creative activity, in which the learner must exert effort to clarify concept meanings in specific domain knowledge, by identifying important concepts, establishing the concepts relationships, and denoting their structure. Also, concept mapping is regarded as a self-regulative and challenging activity as it fosters reflection on learners' understanding of concepts and their relationships, enabling learners to monitor their learning process and to focus attention on their learning needs (Novak & Gowin, 1984; Cañas et al., 2003). In educational settings, where assessment is aligned with instruction in order to support and enhance the learning process, concept mapping and subsequently concept maps are considered a valuable tool of the assessment toolbox. Various applications of concept maps in education and a number of concept mapping software tools are presented in (Cañas et al., 2003).

Towards the direction of interweaving assessment and instruction, and exploiting the value of concept maps as assessment and learning tools, we are developing an adaptive web-based concept map tool, named COMPASS (COncept MaP ASSessment tool). Based on an assessment goal that the learner selects from a set of proposed goals, COMPASS engages learners to the "assessment+learning" process through a set of assessment activities. The activities address specific assessment outcomes and employ various concept mapping tasks. COMPASS supports the identification and the qualitative analysis of errors presented on the learner's map. The results are further exploited for the qualitative diagnosis of the learner's knowledge (e.g. unknown concepts, false beliefs) and the quantitative estimation of the learner's knowledge level on the activity, according to assessment criteria defined by the teacher. Aiming to individualize feedback, COMPASS provides to the learner different informative and tutoring feedback components, tailored to his/her knowledge level, preferences and interaction behaviour. The provided feedback aims to stimulate the learners to reconsider their beliefs, reflect on them and reconstruct/refine their knowledge structure. The provision of adaptive feedback is considered as one of the discriminative characteristics of COMPASS in comparison to other tools. The paper is organized as follows. In Section 2, an overview of the COMPASS tool is presented. In section 3, the architecture of the tool is provided focusing on the representation of the domain knowledge and the learner model, the diagnosis of the learner's knowledge and the generation of the adaptive feedback. In Section 4, the paper ends with conclusions and our plans for further research.

2 An Overview of COMPASS Tool

The aim of COMPASS tool is twofold: to assess the learners' understanding as well as to support the learning process. In particular, COMPASS serves (i) *the assessment process* by providing a variety of assessment activities (through specific concept mapping tasks, see section 3.1.1) and applying a scheme for the qualitative and quantitative estimation of the learner's knowledge (see section 3.2), and (ii) *the learning process* by providing different informative and tutoring feedback components, tailored to each individual learner, through the "Knowledge Reconstruction + Refinement" (KR+R) process.



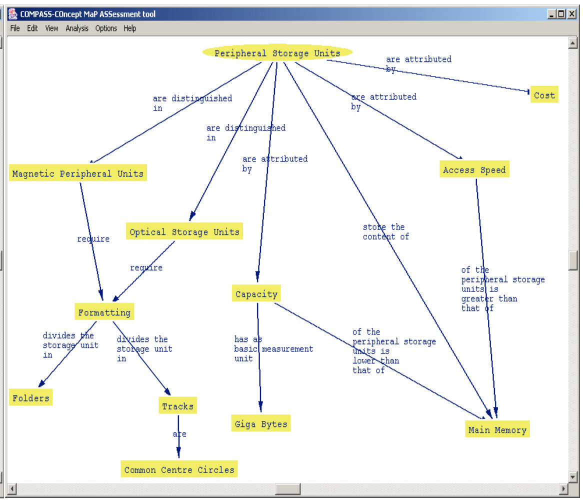


Figure 1. A screenshot of COMPASS at the beginning of a "concept-relationship list completion/evaluation" task

Figure 2. The concept map constructed by a learner for the concept mapping task, depicted in Figure 1.

Figure 1 depicts a screenshot of the COMPASS tool, as it appears to the learner at the beginning of a "concept-relationship list completion/evaluation" task (a description of the types of concept mapping tasks is given in Section 3.1.1). Concepts and relationships to be completed are indicated by four question marks. Figure 2 illustrates the concept map constructed by a learner for the specific mapping task. The toolbar of the learner's interface contains several tools, such as: (i) "Options" that allows a learner to select an assessment goal and an activity, (ii) "File" that allows a learner to "Create", "Load", and "Save" a concept map and "Exit" COMPASS, (iii) "Edit" that allows a learner to "Undo" and "Redo" his/her last action, (iv) "View" that presents the available lists of concepts/relationships according to the mapping task, and (v) "Analysis" that allows a learner to check/verify his/her map and receive the appropriate feedback; the automatic analysis of the map is supported in cases where the mapping tasks employ lists of concepts/ relationships, otherwise the teacher is responsible for the assessment and the provision of feedback..

Based on an assessment goal that the learner selects, COMPASS provides various assessment activities. After the learner has completed the activity or in case s/he asks for support/help, the learner may check/verify his/her map through the "Analysis" tool. In this case, COMPASS activates the "KR+R" process, which includes (i) the diagnosis process for the identification of errors, their qualitative analysis, the qualitative diagnosis of the learner's knowledge and the quantitative estimation of the learner's knowledge level, and (ii) the feedback generation process for the provision of appropriate informative and tutoring feedback components for each one of the errors. More specifically, the following sequence of interactions (stepwise presentation of the feedback components combined with a multiple try strategy) is taken place: (i) *First Step:* COMPASS indicates the error by providing learners with an initiating question (IQ), which gives them the possibility to rethink their beliefs and to identify and check their own errors. The applicability of the step depends on the error category (Table 1) (e.g. for a "missing relationship" error, this step is not applied). Following, the tool enters in a "wait" state, expecting the learner's action. (ii) *Second Step*: If the learner insists on his/her belief, then according to specific rules (see section 3.3) error-task related questions (E-TRQ) or tutoring feedback units and error-task related questions (TFU+E-TRQ) are provided. COMPASS enables the learner to think about the feedback and proceed with any changes; the tool enters again in a "wait" state, expecting the learner's action. (iii) *Third Step:* If an impasse is reached (learner insists on his/her belief) or the learner asks for the knowledge of correct response, then COMPASS informs the learner about the correct response (KCR feedback component). It is important to mention that the whole process is fully controllable by learners who always have the option to select the desired feedback component, ignoring the ones provided by the tool.

3 The Architecture of COMPASS

The architecture of COMPASS, illustrated in Figure 3, is comprised of five modules: (i) the *Interaction Monitoring Module* (IMM), which is responsible for (a) collecting data concerning the learner's observable behaviour, (b) activating the other modules according to the learner's actions (i.e. activation of the DM after the accomplishment of an activity and the AFGM after the completion of the activity or in case the learner asks for support/help), and (c) updating the LM with the newly acquired information (e.g. feedback components provided, duration of the activity's elaboration, etc.), (ii) the *Diagnostic Module* (DM) that supports the assessment of the learner's concept map, based on the similarity of the map with the expert's one, (iii) the *Adaptive Feedback Generation Module* (AFGM), which is responsible to generate the appropriate feedback, according to the learner's knowledge level, preferences and interaction behaviour, (iv) the *Presentation Module* (PM), which is responsible for the presentation of (a) the constituent parts of the concept mapping task that will be available to the learner during the accomplishment of the activity (received from the DK), and (b) the feedback after generated by the AFGM, and (v) the *Data Storage* (DS), containing *the Domain Knowledge* (DK) and the *Learner Model* (LM). Below, we discuss in more detail the Data Storage, the Diagnostic and the Adaptive Feedback Generation Modules.

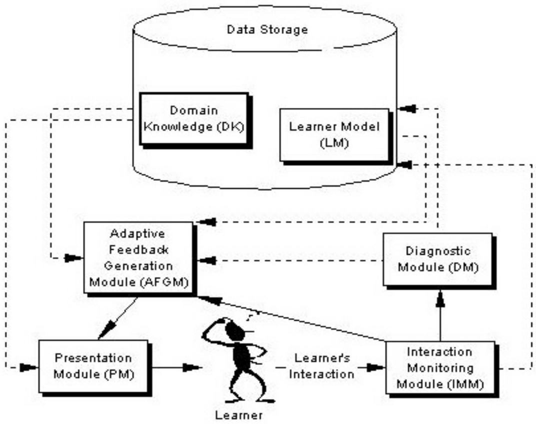


Figure 3. The main modules of the architecture of COMPASS.

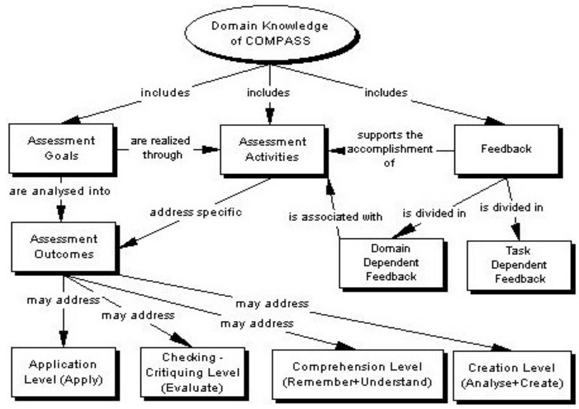


Figure 4. The constituent parts of the Domain Knowledge.

3.1 Representing the Domain Knowledge and the Learner Model: the Data Storage

3.1.1 The constituent parts of the Domain Knowledge

The domain knowledge of COMPASS is based on the notion of the *assessment goals* that the learner can select. A goal corresponds to a fundamental topic of the subject matter and is associated with a set of concepts, called *fundamental concepts.* Each goal is further analysed to specific *assessment outcomes*, which are realised through various *assessment activities*. The outcomes may address the *Comprehension level* (Remember + Understand), the *Application level* (Apply), the *Checking-Critiquing level* (Evaluate), and the *Creation level* (Analyse + Create) (Gogoulou et al., 2004). The feedback, aiming to support the learning and the reflection process, is divided into *domain dependent feedback* and *task dependent feedback.* The constituent parts of the domain knowledge are illustrated in Figure 4.

Assessment Activities. The design of the activities is based on the *AssessToLearn* framework, which is proposed in (Gouli et al., 2003), following a three-step process. According to the steps of the framework, an assessment activity accomplishes specific *assessment functions,* such as:

- *Ascertaining the Learners' Prior Knowledge - Activating Knowledge*: the assessment activity aims to enable (a) the teachers to (i) elicit learners' prior knowledge, (ii) identify learners' initial knowledge level as far as the new concepts are concerned, and (iii) diagnose learners' unknown concepts, incomplete understanding, and false beliefs, and (b) the learners to activate their existing knowledge,
- *Promoting Knowledge Construction & Identifying Conceptual Changes - Constructing & Enriching Knowledge*: the assessment activity aims to enable (a) the teachers to (i) monitor/assess learners' progressive changes during the instruction, (ii) promote learners' knowledge construction and the development of high level cognitive skills such as reflection, revision and critical thinking, and (b) the learners to monitor how their learning progresses, and whether their knowledge is revised and/or enriched with and incorporates effectively new knowledge, and
- *Assessing Knowledge Construction - Refining Knowledge*: the assessment activity aims to enable (a) the teachers to (i) capture the growth in learners' overall understanding, and (ii) identify how learners' knowledge has been constructed after the completion of instruction, and (b) the learners to refine their knowledge and draw conclusions about the degree of achieving the expected assessment outcomes.

Depending on the outcomes and the functions that the assessment activities address, the activities may employ various concept mapping tasks such as (i) the construction of a map either from scratch ("*free construction*"), or using a list of concepts ("*concept list construction*"), or using a list of concepts/relationships ("*concept-relationship lists construction*"), (ii) the evaluation of a map (i.e. the evaluation and consequently the correction of the map in case of the identification of any errors) either from scratch ("*free evaluation*"), or using a list of concepts/relationships ("*concept-relationship lists evaluation*"), (iii) the extension of a map either from scratch ("*free extension*"), or using a list of concepts ("*concept list extension*"), or using a list of concepts/relationships ("*concept-relationship lists extension*"), (iv) the completion of a map (i.e. the construction of a map by filling the requested concepts and relationships) either from scratch ("*free completion*"), or using a list of concepts ("*concept list completion*"), or using a list of relationships ("*relationships list completion*"), or using a list of concepts/relationships ("*concept-relationship lists completion*"), and (v) a combination of the abovementioned tasks such as the completion and evaluation of a map using a list of concepts/relationships ("*concept-relationship lists completion/ evaluation*").

The assessment activities may have different difficulty level and different degree of importance for the accomplishment of a goal, depending on the addressed assessment outcomes and assessment functions. An activity is related with various concepts that may be represented on the concept map. These concepts have different degree of importance for the accomplishment of the activity. The concepts that are basic concepts for the specific task/map and should be represented on the map, are named *fundamental concepts of the task/map*. Concepts that analyse and/or clarify the fundamental concepts are named *useful concepts of the task/map* while concepts that are not included in the above categories but they may be represented on the map (i.e. their meaning is correct and they are related to the central concept of the map and to the fundamental/useful concepts) are named *related concepts of the task/map*. For example, for the concept map depicted in Figure 2, the concepts "Magnetic Storage Units", and "Optical Storage Units" are characterized as fundamental concepts, the concept "Formatting" is a useful concept, while the concept "Common Centre Circles" is a related concept. It is important to mention that the categorisation of the concepts depends on the assessment activity; the same concepts in the context of other activities may be characterized differently. This categorization of concepts plays significant role in the assessment process; different assessment criteria may be defined based on this categorization (e.g. completeness of fundamental concepts of the task/map) and different weights may be assigned to the concepts according to their degree of importance. Furthermore, an activity is related with the propositions that are represented on the map constructed by the teacher (expert's concept map). For these propositions, different weights may be assigned denoting their degree of importance for the accomplishment of the activity.

Summarizing, an assessment goal is realised through various assessment activities for which the domain knowledge of COMPASS keeps information about (i) the addressed assessment functions, (ii) the level of the addressed assessment outcomes, (iii) the type of the concept mapping task employed, (iv) the lists of concepts and/or relationships that may be available according to the mapping task, (v) the difficulty level, (vi) the degree of importance for the accomplishment of the assessment goal, (vii) the assessment criteria employed, (viii) the concepts that may be represented on the concept map, their categorization and their weights, and (ix) the propositions that are represented on the expert's concept map and their weights.

Feedback. Feedback is considered as one of the most important sources of information to assist learners in restructuring their knowledge (Mason & Bruning, 2001). Several research efforts provide feedback to learners according to specific common errors identified on their concept maps (Cimolino et al., 2003; Chang et al., 2001), without taking into account any learner's individual characteristics or needs. More specifically, in (Cimolino et al., 2003), the system analyses the learner's map by comparing it with the expert's map and provides hints (feedback strings defined by the teacher) about specific errors such as missing propositions. In (Chang et al., 2001), the system gives appropriate hints to the learner in the form of partial propositions. Having as an objective to provide individualized feedback, which tutors and guides the learners and subsequently enables them enrich/reconstruct their knowledge structure, COMPASS offers different informative and tutoring feedback components (ITFC). The ITFC include (i) an initiating question (IQ) consisting of the learner's belief, and a prompt to think of the concepts included in the proposition and to write any keywords describing the concepts, (ii) specific error-task related questions (E-TRQ) aiming to redirect the learner's thinking and give a hint for correcting the error and completing the task, (iii) tutoring feedback units (TFU) relevant to concepts/relationship included in the map, aiming to allow the learner to review educational material relevant to the attributes of the correct response, and (iv) the knowledge of correct response (KCR), which is the correct proposition as it appears on the expert's map. The ITFC concerning the E-TRQ and/or the TFU are provided according to the learner's individual characteristics and needs (i.e. learners' knowledge level, preferences and interaction behaviour).

The DK of COMPASS incorporates the error-task related questions (task dependent feedback) as well as the tutoring feedback units (domain dependent feedback). Regarding the error-task related questions, the DK includes the form of the questions, providing flexibility to the teacher in case of any modifications. The form of the questions is differentiated according to the error categories that may be identified on the learner's map. For example, in case of a “missing relationship” error, the question has the form “Do you consider that you could add a relationship between the concepts of [C1] and [C2]?”, while in case of a “superfluous relationship” error, the question has the form “Do you really believe that the concepts [C1] and [C2] are related with the specific relationship?”, where [C1] and [C2] are concepts represented on the learner’s map. The form of the questions that is associated with each error category (Table 1) as well as examples of the questions are presented in (Gouli et al., 2004).

The tutoring feedback units, included in the DK, concern (i) the concepts represented on the expert’s concept map and/or the concepts included in the provided list of concepts (if a list of concepts is provided according to the mapping task) (TFUC), and (ii) specific propositions that the teacher anticipates errors/false beliefs (TFUP). TFUC are organised in two levels, TFUC1 and TFUC2 differing on the level of detail of the feedback information. TFUC1 present the corresponding concept in general and they are independent of the mapping task (i.e. the same TFUC1 can be provided for different mapping tasks, which include the specific concept). TFUC2 present the corresponding concept in more detail, focusing on the relationships of the concept with the other concepts of the map. Thus, TFUC2 depend on the concepts that may be represented on the particular concept map. The definition of TFUC2 is optional, depending on the definition of TFUC1 and the degree of importance of the specific concept. The feedback units (TFUC1 and TFUP) are associated with educational material consisting of knowledge modules, which constitute multiple representations of the concepts included in the proposition (i.e. a definition/description, an example, and/or an image of the concepts). The TFUP have the following form: “*Educational Material*. You believe that [C1] R [C2]. If it is true then *Consequence Text*. Do you insist on your belief?”, where (i) *Educational Material* (optionally defined by the teacher) is consisted of knowledge modules (i.e. definition/description, example, image) and concerns information about the concepts [C1] and/or [C2] included in the false proposition, (ii) the triple [C1] R [C2] is the false proposition which appears on the learner’s map, and (iii) *Consequence Text* is information that describes a possible consequence of the learner’s false proposition (defined compulsory by the teacher). The DK includes for specific propositions, represented on the expert’s map, the educational material and the consequence text. An example of TFUP, after its generation by the AFGM, for the false proposition “[Capacity] of the peripheral storage units is lower than that of [Main Memory]” represented on the learner’s map in Figure 2, is the following: “*The capacity of the hard disk is usually more than 30 Gigabytes.* You believe that [Capacity] of the peripheral storage units is lower than that of [Main Memory]. If it is true then *it is possible to store your favourite games in Main Memory*. Do you insist on your belief? ”.

Summarizing, the domain knowledge of COMPASS, as far as the feedback is concerned, keeps information about (i) the form of the E-TRQ, and (ii) the TFU concerning the TFUC1, TFUC2 and TFUP and subsequently the supported corresponding knowledge modules.

3.1.2 The Learner Model

The LM reflects specific characteristics of the learner and thus it is used as the main source of the adaptive behaviour of COMPASS. The information held is divided into *domain dependent information* and *domain independent information*. As far as the domain dependent information is concerned, the LM keeps information about: (i) the learner’s knowledge level (qualitative and quantitative estimation) with respect to the assessment goals/activities that s/he selects, (ii) the learner’s errors identified on his/her map, and (iii) the learner’s behaviour during his/her interaction with the tool in terms of the number of times that feedback was asked, ITFC proposed/selected, frequency of errors made, time of response, etc. As far as the domain independent information is concerned, the LM keeps general information about the learner such as username, profession, learner’s favourite feedback components and knowledge modules (i.e. definition/ description, example, image), last time/date the learner logged on/off. The LM is dynamically updated during the learner’s interaction with COMPASS in order to keep track of the learner’s “current state”.

3.2 Diagnosis of Learner’s Knowledge: the Diagnostic Module

The DM receives input from the IMM, which gathers information about the learner’s interaction with COMPASS and updates the LM as far as the learner’s knowledge level and the learner’s errors identified on the map are concerned. In more details, the DM is responsible for (i) the *error diagnosis,* i.e. the identification of errors on the learner’s map (based on the similarity of the learner’s map with the expert’s one) and their qualitative analysis, in order to identify learner’s unknown concepts, false beliefs and incomplete understanding, (ii) the *qualitative diagnosis of the learner’s knowledge* based on the error categorization proposed in Table 1, and (iii) the *quantitative estimation of the learner’s knowledge level* on the central concept of the map and subsequently on the assessment activity, which is further exploited by the AFGM for generating individualized feedback.

Qualitative Diagnosis of Learners' Knowledge	Categories of Learners' Errors
Unknown Concepts	*Missing concept and its relationships:* specific concepts, which should be represented on the map and have been defined as fundamental concepts for the specific task/map, are missing.
Incomplete Understanding	*Incomplete relationship:* the relationships between two concepts are incomplete, as several relationships are missing (e.g. concepts [C1] and [C2] are related with m relationships on the expert's map, while on the learner's map n relationships appear, where n<m).
	Missing relationship: the relationship between two concepts that should be related is missing.
False beliefs	*Superfluous relationship:* two concepts are related although they should not.
	Incorrect relationship: two concepts are related with an incorrect relationship, which should be substituted.
	Incorrect concept: a concept is related to an incorrect concept, which should be replaced with another concept.
	Superfluous concept: a superfluous concept appears, which should be deleted.
	Incomplete propositions: a concept (presented on the learner's map) is not related to all the required concepts because the related concepts are missing.

Table 1: Qualitative Diagnosis of learners' knowledge based on different categories of errors

In order to formulate a framework for the qualitative diagnosis of learners' knowledge, we analysed a sample of learners' concept maps resulted from the accomplishment of various concept mapping tasks (Gouli et al., 2003). In particular, we investigated repeated patterns of valid and invalid propositions and identified several common errors that led us draw conclusions about their knowledge. The identified errors are classified to the categories (qualitative analysis) presented in Table 1 and address the entire aforementioned concept mapping tasks (e.g. the categories of incorrect relationship, incorrect concept, and superfluous concept may be identified in a "concept-relationship completion" task, while all the categories of errors may be identified in a "free-construction" task).

The qualitative diagnosis of the learners' knowledge on an assessment activity concerns the identification of the unknown concepts, incomplete understanding and false beliefs. The learner's knowledge level is quantitatively estimated according to assessment criteria defined by the teacher. COMPASS provides flexibility to the teacher in terms of (i) defining different assessment criteria, and (ii) assigning weights to these criteria denoting their relative degree of importance for the specific assessment activity taking into account several factors such as the addressed assessment outcomes and the difficulty level of the activity. Indicative assessment criteria may be: (i) the completeness of fundamental concepts of the task/map, (ii) the completeness of relationships among the fundamental concepts of the task/map, (iii) the validity of specific weighted propositions, (iv) the error categories identified on the map (taking into account the weights that may be assigned to the different error categories). Based on the assessment criteria, the learners' knowledge level on a specific assessment activity is assigned to one of the characterizations {Insufficient (Ins), Rather Insufficient (RIns), Average (Ave), Rather Sufficient (RSuf) and Sufficient (Suf)}. For the quantitative estimation of the learner's knowledge level on an assessment goal, the degree of importance of the activities for the accomplishment of the goal is taken into account.

3.3 Generating Adaptive Feedback: the Adaptive Feedback Generation Module

The AFGM is responsible for the generation of feedback, tailored to each individual learner. More specifically, the AFGM determines which one of the ITFC (E-TRQ and TFU+E-TRQ) should be provided to the learner, according to his/her interaction behaviour, and/or preferences and/or knowledge level. The AFGM receives the content of the TFU as well as the form of the E-TRQ from the DK. In case of the TFU+E-TRQ, the TFU included in the DK in conjunction with the E-TRQ (according to the error categorization) are provided to the learner. For example, for the false proposition "[Capacity] has as basic measurement unit [Gigabytes]" ("incorrect concept" error), which is represented on the learner's map of Figure 2, the AFGM uses the available knowledge modules of TFU (i.e. (i) a description for each one of the concepts included in the proposition, defining their meaning, and (ii) an example concerning the specific concepts, such as an example giving the capacity of several storage units, comparing the storage units as far as their capacity is concerned, and explaining the different measurement units) in conjunction with the E-TRQ "Do you really believe that the [Capacity] has as basic measurement unit [Gigabytes]?", in order to generate the TFU+E-TRQ feedback.

The AFGM uses an adaptation scheme (Gouli et al., 2004) including several rules for planning/deciding the type and the content of the feedback that should be provided to the learner. AFGM exploits information from (i) the learner model (i.e. learner's knowledge level, preferences (i.e. preferences on ITFC and on knowledge modules) and interaction behaviour (i.e. knowledge modules of TFUC1 or TFUP more often provided, ITFC more often provided and frequency of errors made), (ii) the DM, concerning the errors identified on the learner's map and their qualitative analysis (categories of errors), and (iii) the DK concerning the content of the TFU. Indicative rules that have been adopted in the adaptation scheme are (for more details see (Gouli et al., 2004)):

(i) If the knowledge level of the learner has been evaluated as (Ins) or (RIns) on the assessment activity, then both TFU and E-TRQ are provided (TFU+E-TRQ).
(ii) If the knowledge level of the learner has been evaluated as (Suf) or (RSuf) on the assessment activity, then E-TRQ is provided.
(iii) If the knowledge level of the learner has been evaluated as (Ave) on the assessment activity, then according to the learner's preferences (ITFC preferred) and interaction behaviour (ITFC more often provided/selected and frequency of errors made), E-TRQ or TFU+E-TRQ is provided. For example, (a) if the learner's favourite ITFC is E-TRQ but TFU+E-TRQ is more often provided, then TFU+E-TRQ is provided, (b) if the frequency of a specific error identified on the learner's map is minimal (e.g. the learner's map includes very few incorrect relationships), then E-TRQ is provided.

The design of the functionality of the AFGM was carried out in parallel to two empirical studies that we conducted as a pilot evaluation. The two studies were carried out during the winter semester of the academic year 2003-2004, in order to investigate whether the design of the feedback components, as well as the adopted adaptation scheme, could stimulate learners to reflect on their beliefs and appropriately revise their maps (Gouli et al., 2004). The results, even performed on a limited number of subjects, have been encouraging, indicating that the feedback provided led the majority of the students to reconstruct/refine their knowledge and accomplish successfully the assessment activity.

4 Conclusions and Further Research

COMPASS is an adaptive web-based concept map tool, aiming to support learning through the assessment process. In this paper, we presented the architecture of COMPASS and its modules, focusing on the representation of the domain knowledge and the learner model, the diagnosis of the learner's knowledge and the generation of the adaptive feedback. The discriminative characteristics of COMPASS are: the conceptual structure of its domain knowledge, which is based on the notion of assessment goals that the learner can select, the qualitative diagnosis process and the quantitative estimation of the learner's knowledge level, the adoption of multiple informative and tutoring feedback components and the stepwise feedback presentation, the adoption of error-task related questions based on a categorization of learners' common errors, the adoption of the two levels of the tutoring feedback units and the adaptation of feedback to the learner's knowledge level, preferences and interaction behaviour.

As the development phase of COMPASS is in progress, our near future plans include the completion of the implementation of the Diagnostic Module and the Adaptive Feedback Generation Module. Afterwards, we plan to carry out a series of empirical studies in classroom environment, in order to evaluate COMPASS regarding the effectiveness of the diagnosis process, the provided feedback components and the adaptive feedback scheme. Also, further research is in progress concerning (i) the enrichment of the tool's functionality with more adaptive capabilities concerning the provision of the activities of a specific assessment goal gradually according to the learner's knowledge level and his/her expertise in constructing concept maps, (ii) the development of an authoring tool for the administration of the domain knowledge, and (iii) the provision of visual feedback (graphical annotation of the errors, following the proposed error categorization).

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CONCEPT MAPS AND THE DIDACTIC ROLE OF ASSESSMENT

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Abstract. The assessment is presently looked at not only as a process of evaluating the student's knowledge of a specific subject, but at its own didactic function. As such, the assessment allows the teacher to organize and regulate the teaching process and, with the simultaneous access to assessment and metacognition tools, it seeks to reinforce the student's control over his learning process, hence facilitating the student's meaningful learning.
In this communication, several examples are given that show how conceptual maps may be useful in an assessment that seeks not only to find if the student has acquired the knowledge that is a part of the objectives previously defined, but also find out what the student knows, understands, or is able to achieve on his own. The students' creation of conceptual maps not only contributed to a refinement of their cognitive structuring, but also improved their emotional and social behaviour.

1 It is important to reinforce the didactic role of assessment

It is classically known that assessment had eminently social functions such as classification, selection, certification and students' placement. With the advent of cognitivism and upon recognizing that assessment was fundamental in the development of the teaching process and that the time during assessment could (and should) be used as an excellent time for learning, a reinforcement of the assessment's prescriptive character occurred, and henceforth assessment began to have a relevant didactic character. As such, assessment started to assume important roles such as organizing and regulating the teaching process, reinforcing the student's control over his own learning and facilitating meaningful learning.

Assessment assumed its condition of an intrinsically subjective process (even the so called objective instruments only eliminate subjectivity related to correction, not classification criteria or elaboration options) and became a much more multifaceted process that assumed several forms and employed various instruments as needed to reach specific goals. While classic assessment favored grading and ranking aspects, primarily for administrative purposes, modern assessment favored didactic aspects, hence becoming much more prescriptive.

Besides involving a sound conception, widening the process of gathering and interpreting information, and making well founded judgments, assessment assumed the need for making the right decisions, based upon well founded thought (Beeby, 1977, Tenbrink, 1981), becoming more formative, and even more forming. In fact, traditional formative assessment ("évaluation formative", in French), which is very retroactive in nature and primarily related to the teacher's pedagogic strategies, in which the teacher seeks to control the student's process, is being supplemented by a forming assessment (évaluation formatrice"), where the emphasis resides in the student's learning process under the student's control, therefore becoming more proactive than retroactive (Bonniol, 1986, p. 126 and Abrecht, 1994, p. 49).

Nowadays, in addition to a converging assessment that focuses on finding out if the student knows, understands, or is able to execute a predetermined task, the emphasis is shifting towards the need to also assume a divergent assessment with the goal of finding out what the student knows, understands or is able to do.

2 What are concept maps?

Novak's concept maps are tools that represent knowledge, and were first developed in 1972 by Novak and his collaborators at Cornell University (Novak, 1990a, 1997; Moreira, 1997). They are directly related to Ausubel's original theory and have been proven useful in facilitating meaningful learning (Novak, 1990a, 1991; Moreira, 1997; Moreira and Buchweitz, 1993). They consist of hierarchic diagrams that represent concepts and how these concepts interrelate, focusing on showing the concept's organization within the cognitive structure of an individual on a given subject (Moreira and Buchweitz, 1993; Novak and Gowin, 1999). Although usually hierarchically organized, concept maps should not be confused with organigrams or flow diagrams because they do not imply a sequence, time frame, or a sense of direction, nor do they set organizational or power hierarchies (Moreira, 1999). The fact that two concepts are linked is important since it shows that, for the person creating

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the map, there is a relation between these two concepts. Arrows may be used on these lines to provide a sense of direction and association, but that is not mandatory. What is important is for the map to become an instrument that clearly shows the meanings attributed to the various concepts and how these concepts relate to each other within the context of a given body of knowledge. Concepts, and the words linking them, create an assertion that projects the meaning of the conceptual connection (idem).

Concept mapping is a technique that exposes the concepts and assertions hidden within the cognitive structure of each student and it is of great importance since it shows the changes occurring in this cognitive structure, clarifies misconceptions and superficial interpretation in the teaching/learning process, and allows the teacher and student to exchange points of view on the validity or absence of a link between two concepts. In addition, the process of creating concept maps may also contribute to the development of a cooperation between the student and teacher in the sharing of meaning, where "making and remaking concept maps, and sharing it with others may be considered a team effort in the sport of thinking" (Novak, 1990a).

The importance of the concept map role in Science Teaching has been demonstrated since the publication, in 1990, of a special edition of the Journal of Research in Science Teaching about this subject that includes an article by Al-Kunifed & Wandersee (1990) citing around one hundred references related to the use of the maps. Since then, considerable research has validated the usefulness of concept maps in meaningful learning.

3 Concept Map Analysis

Although Novak and Gowin (1999), based on Ausubel's learning theory, proposed several criteria that allow the rating of concept maps, we believe that what is most important is to try to interpret the information that the maps provide us regarding the manner in which students structure, prioritize, differentiate, relate and integrate concepts and exhibited misconceptions. Concept maps are analyzed primarily under a holistic perspective, emphasizing the order of concepts and the meaningful connections between them (Valadares and Graça, 1998).

Therefore,

- An overall analysis of the concept map is performed to verify if it is:
  - primarily linear, exclusively or almost exclusively from top to bottom, which manifest a poorly defined cognitive structure, with problems regarding the links between the concepts;
  - or extensively branched out, which may indicate a rich cognitive structure, if concepts are well linked, progressively defined and integrally inter-linked.
- A detailed analysis is then performed to check;
  - if the links between the various concepts are correct or if they show misconceptions:
  - if the map is well laid out, that is, if it shows a progressive differentiation in a correct and effective manner;
  - if there are valid and meaningful cross-links, that is, if it shows correct
  - integrative reconciliation;
  - if there are valid examples along the bottom (with an hierarchy from top to bottom) or on the outer edges (with an hierarchy from the center out).

4 Concept maps as metacognitive instruments in a "forming" assessment

"Forming" assessment ("évaluation formatrice", in French) was postulated by a group of researchers at d'Aix Marseille Academy (Abrecht, 1994, p. 48). It focuses on "control assured by the student" rather than the traditional formative assessment where "control is primarily related to the pedagogic strategies of the teacher" (J. J. Bonniol, 1986, p. 126, in Abrecht, 1994, p. 49). So, concept maps are excellent tools that help the student in learning how to learn and in gradually taking control of his own learning. We agree with Novak (1991) that the teaching of science is "conceptually opaque". This means that the materials provided to students have little or no value in assisting students to visualize the structure of the subjects they study, that is, the links between concepts. It is clear that people think with concepts and it is the scientifically correct links between them that give meaning to the statements memorized by students and to the problems that are solved using "formulas". Meaningful content must be made conceptually transparent to students to allow for meaningful learning. Students need some help in constructing and reconstructing their conceptual structures, and, based upon these structures, they interpret facts, postulates, and memorize rules.

Concept maps assist teachers in controlling the students' learning since "they may be used to map out a route for organizing and presenting knowledge to students, as well as for finding students' alternative conceptions" (Novak, 1991, p. 38). It is also important that they become excellent tools in helping the student control his own learning. Actually, besides helping in building new knowledge and learning key concepts, concept maps will help the student with learning how to learn (Novak, 1988b, 1990a, 1990b, 1991; Novak and Gowin, 1999).

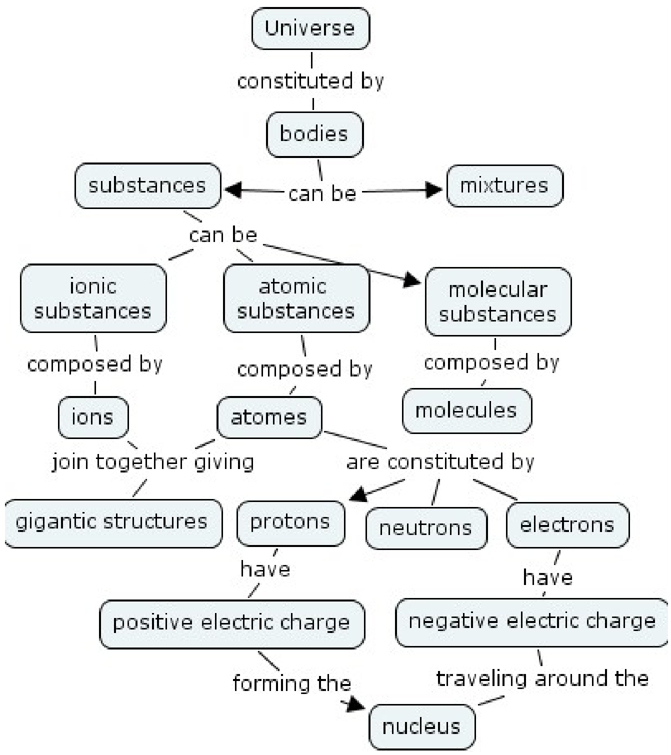
Also, concept maps are shown to be excellent in assessing students' prior knowledge, which is of great importance since, according to Ausubel (1980), prior knowledge is a determining factor in subsequent learning. If we take into account that student pre-conceptions are persistent and that conceptual change is a slow process, teachers should be motivated to search for more efficient teaching strategies that allow students to openly express their pre-conceptions (Driver, 1996). According to Novak (1997), investigating pre-conceptions and misconceptions revealed that traditional teaching does little to change them, and that meaningful learning and strategies to promote it are necessary to overcome such conceptions and build new and more meaningful ones.

5 Concept maps and the learning of Chemistry

We created the maps presented below using CmapTools from the Institute for Human and Machine Cognition. They faithfully depict hand drawn concept maps created by some of our students.

5.1 A map that helped in detecting a teaching deficiency

This map was created by a student in his eighth year of formal education during a chemistry class on materials and their classification.



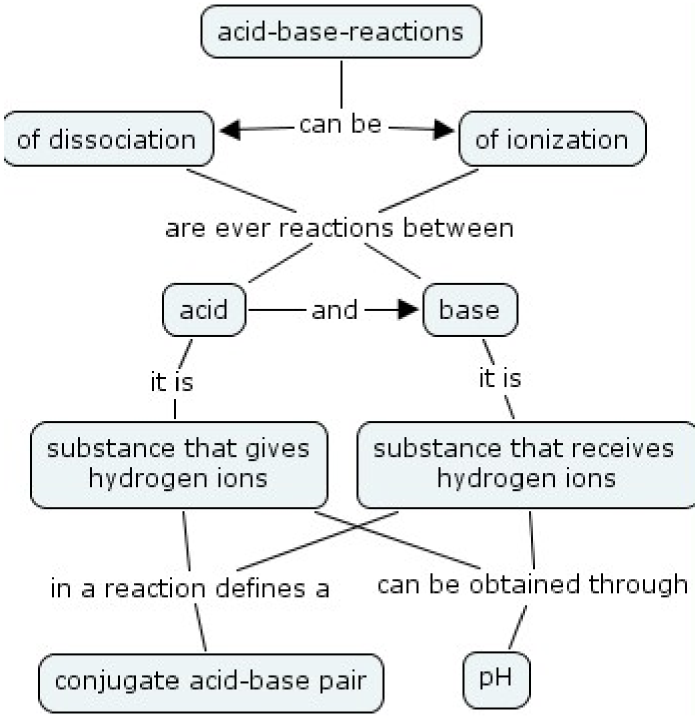
An analysis of this and other maps created by the students revealed two important teaching deficiencies. First, enough emphasis had not been given in differentiating the concepts of body (an amount of matter with a given mass) and material (classified either as a substance or a mixture). Secondly, the giant structure designation had only been addressed regarding ionic and atomic crystals, not regarding molecular crystals such as ice.

These subjects were then taught to the students, and subsequent maps did not reflect the previous deficiencies.

5.2 Two maps that show significant progress in the understanding of the acid-base subject

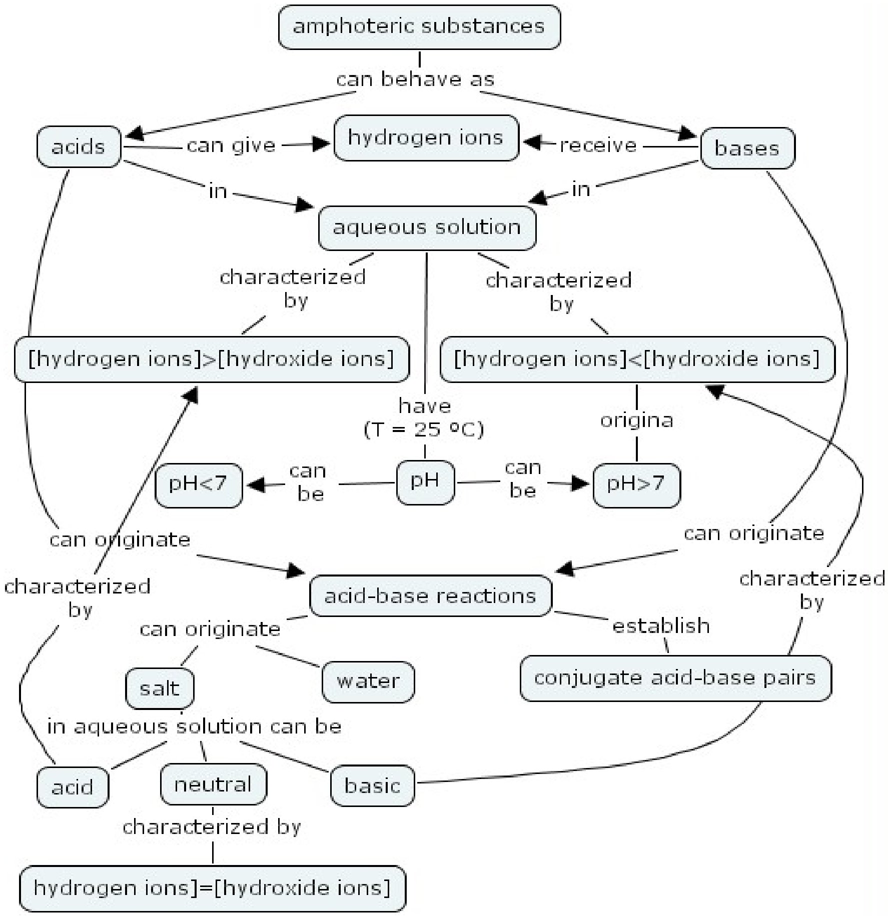
In order to analyze the effects of implementing a learning strategy in a constructivist environment for teaching the acid-base subject, the performance of two tenth grade classes deemed equivalent at the outset were compared. In one of the classes, particular attention was given to the construction of concept maps by the students, both individually and as a team; this became the experimental group. The other class was subjected to a traditional classroom teaching environment and was used as a control group.

The following map was created by a student in her tenth year of formal education, during the first phase of learning about acid-base reactions.



An analysis of this map pointed to the fact that the student did not yet have a clear and correct understanding of the differences between dissociation and ionization reactions, leading to her misconception of pH, which was confused with the acid-base indicator concept. During the following class period, care was taken in verifying what the students' understanding of these concepts was and in providing her with the resources that enabled her to improve her knowledge in this area. Similar techniques were used regarding misconceptions of other students evidenced in the maps that they created.

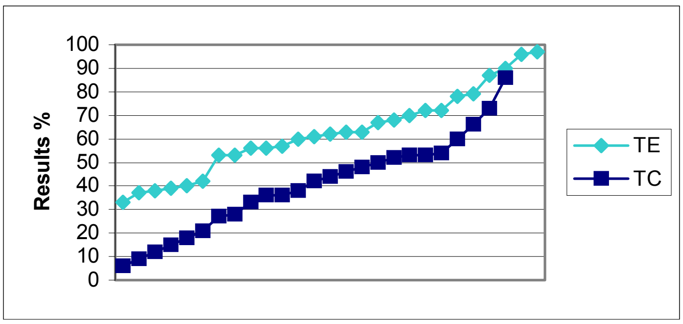
The following map was subsequently created by the student that created the map above. One can easily recognize that there is a broader differentiation progressive from the way the student expressed how she now perceives concepts to be connected.



The student also demonstrates an understanding of the acid and base idea according to Bronsted's theory, not just exclusively related to aqueous solutions. As new material on the subject was presented, the student gained broader knowledge, and was able to relate new concepts to more general ones.

For the most part, students that worked with concept maps developed a more significant and correct knowledge of the acid-base concept than the average student in the control group (TC), showing more in-depth understanding of the subject matter.

The superior performance of the experimental group (TE) was evidenced by the results of a post test based on an answering model and grading guide. Test results are shown in the following table.



5.3 Concept maps and the improvement of personal interaction in the classroom

Besides the aspects related to progress of a cognitive nature, one must also note the improvement in the students' personal interaction and the reinforcement of their self esteem and motivation for further learning. Debate within the experimental class, generated by the construction of maps in a team environment, or a discussion about a specific map, provided each student with a platform for expressing his or her point of view and for communicating to other students at an understandable level, even assuming the role of tutor.

This aspect proved to be very important. Record of observations in the classroom showed that in attempting to verbalize his or her own idea on a specific subject with the intent of communicating this idea to others, students were forced to re-think and analyze what they wanted to verbalize, and, in doing so, were able to find further discrepancies and mistakes in their idea; that is, the student was forced to search for an alternate formulation for the same idea which, in turn, helped to broaden the student's point of view. The verbal interaction among students helped to keep them focused and, in some instances, to pay more attention to a classmate than to the teacher.

During the creation of concept maps by a group of students, special attention was given to promote coordination and assignment of tasks within the group to enable students to continually provide and receive assistance among themselves. This way, before starting the proposed task, the team elements established who the moderator would be, who the spokesperson would be, and who would be responsible for drafting the maps.

Another aspect that should be emphasized is the fact that students gradually showed more interest in debate, as they gained more emotional control to face the "conflicts" generated by the difference of ideas on the same subject and that, in turn, translated into accomplishing the construction of the maps.

Comments such as "You are really stupid!", "You don't get any of this….", and "You were better off saying nothing." were slowly replaced with "Maybe you're right…", "And what do you think?" or "How do you explain that?"

Gradually, several students demonstrated their ability to draw parallels among their points of view without attributing their differences to incompetence or lack of information. We feel that debating was also crucial in allowing to show the importance of communication and interchange of ideas, establishing a need for a climate of acceptance and mutual respect.

Conclusion

Concept maps, created by our students either individually or in group work, have shown to be useful in many ways. They have allowed us to collect data on the meanings that students attribute to certain concepts, particularly regarding misconceptions that they may have. Their use, as an analytical instrument of conceptual knowledge and metacognitive knowledge, awareness and control was useful in obtaining a preliminary and overall idea of the types of representations that the students have and the way that these representations could evolve. We have successfully used them in the assessment of students' prior knowledge, and they have allowed us to plan our teaching in accordance with this knowledge. Since the maps provide an immediate assessment of achieved results and allow for an adopted strategy to be molded to the desired objectives, this formative assessment enabled adjustments in the course of teaching to be made.

In creating the maps, students clarified concepts and became gradually aware of the changes that occurred within their thought processes. This awareness helped them, in some cases, to learn how to learn and to ponder on the nature of acquiring knowledge. In some instances, this was stimulating in the sense that it instilled in the student the notion of being "able" and, in turn, this feeling of personal accomplishment became a driving force in the learning process and a reinforcement of the student's motivation to learn. Another relevant aspect is that diverging opinions among students while working on concept maps helped them to realize the importance of exchanging ideas, achieve personal growth and team knowledge, and also developed positive attitudes towards respecting diverse points of view, tolerance, and understanding the importance of dialogue.

In short, concept maps have proven useful for the purposes reported in numerous research works, specifically in Martinez and Moreira (1997), Novak, Gowin and Johansen (1983) and Boton (1995).

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Concept Maps: Theory, Methodology, Technology
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Pamplona, Spain 2004

A COMMUNITY OF PRACTICE ON CONCEPT MAPPING

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Abstract. This paper describes a community of practice on concept mapping that has been established in Turin, Italy by DSCHOLA. The main purpose of the community is to differentiate the various forms of knowledge representation from each other and to recover the general function of the knowledge representation connected with the learning environment. As a starting point, the community defined and shared a set of founding documents, which includes the Manifesto and the Documentation template. The community aims at structuring and organizing selective criteria in order to produce and make available documentations dealing with good practices on concept mapping.

1 Introduction

The objective of this paper is to introduce map.dschola.it, a community of practice on concept mapping in education. We have an interest in both practical and theoretical issues and are open for collaboration with anyone concerned with the subject.

The initiative was born within a project (see: http://www.dschola.it/en/project/project.php) that, over the last years, has coordinated both theoretical and practical initiatives concerned with ICT in education. It brings together all the efforts made over this period in order to emphasize the debate over the educational use of concept mapping in the school environment as a whole. All these initiatives have been accomplished through the organization of training courses and the production of subject-related material which is available on the Internet.

Map.dschola.it has been active since March 22, 2004, and has already collected a large set of materials and experiences, and a large number teachers from different types of schools have joined.

2 Community objectives

The main purpose of our Community is to discover, to improve, to define and spread best practices in the use of knowledge representation models in school.

We consider knowledge representation to encompass a comprehensive class of models, based mainly on concept nodes: *"Rappresentazioni della Conoscenza"*, KRs in Italian, but we'll refer them here as KRs. KRs include, among others, Concept Maps, Mind Maps, Block Diagrams, and Semantic Networks, Schemes. Within these, concept mapping carries particular relevance.

The map.dschola.it Community:

1. Acquires and recommends new projects and experiences related to Knowledge Representation Models, aimed to document the general function of these representations connected with the learning environment.
2. Defines these general shared criteria to differentiate and build up the KRs, in accordance to the different educational needs.
3. Modifies and adjusts new experiences and provides feedback to satisfy the contributors' counselling needs.
4. Selects samples of KRs to be shared through the Web site. The contributors are then invited to join the community as members and to participate in the general discussions.
5. Supplies tools and resources (guidelines to submit documents, information regarding software, reports and links to websites on related to KRs, and directions on how to use our communication services).

6. Searches for internal criteria for cooperative discussion, in order to define the community objectives and the organization strategies.

As stated in the second objective, one of the purposes of our community is to differentiate the forms of Knowledge Representation from each other. Among these, the community has particular interest in the differences between Concept maps and Mind maps are separated by a sharp edge. The community has found that the distinctions in structure and objectives between these two techniques are very hard to spread amongst the teacher community. These distinctions represent a necessary premise for the key objective 1.

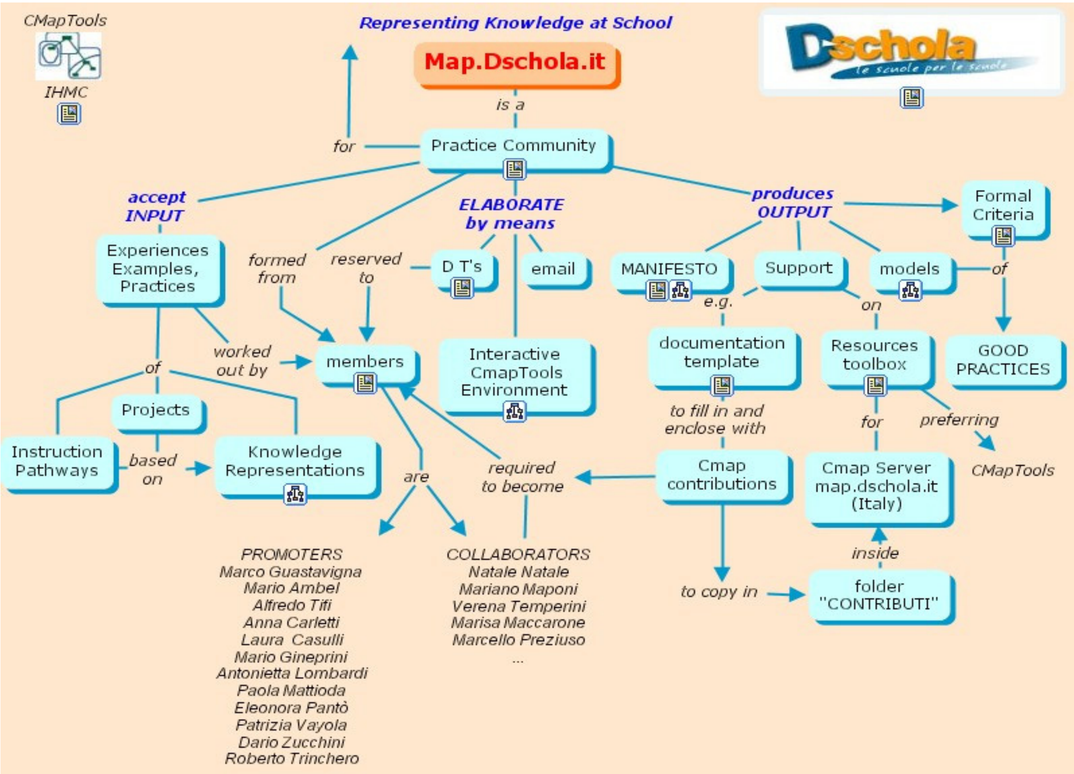

Figure 1. Home page of our Community as a flow chart – Cmap hybrid

3 Group members

The promoters of our community come from all levels of Italian public schools: from primary (or elementary) schools to universities, and most of them have previous experiences with concept mapping in classrooms and in training activities.

Many of the community members had previously met in collaborative frameworks and strengthened their professional bond sharing the same interest for concept mapping and related topics, and it was this collaboration that lead to the establishment of the community of practice. The members of the community come from different regions of the country, and through personal acquaintances and promotion, the list of team members was enriched by contributors to up to 20 members.

4 Community motivations and main remark frameworks

The community began by preparing and sharing some founding documents: the Manifesto, and the Documentation Template to submitted concept maps.

Our community is discussing problems emerging from the evidences of meaningful experiences proposed by contributors. Through these examples we achieve a better awareness of the function of basic principles, thus improving the very criteria for concept mapping.

4.1 KRs

In order to obtain a profitable use of the KRs in school, it is necessary to examine the existing relationships among concept mapping, the students' current knowledge, the methodology to integrate concept mapping in the instructional framework, and finally the exploitation of this methodology in evaluating and supporting the interdisciplinary character.

The Manifesto (see Fig. 2) highlights the research activity already operative within the group. The early results, described in the next section, are supported by our efforts towards:

- Defining the different map typologies, with particular reference to the very changeable concept mapping context. The major interest is focusing on the so-called *structural maps*. These maps express the subjective and in-progress component of the cognitive structure of the students, only when they interact with an "expert" or validated objective knowledge source, as a map achieved from a text;

- Conceptualizing or validating propaedeutical activities, oriented towards the acquisition of concept mapping as a working tool. The sharing, the criticism and the spread of the large number of evaluation criteria concerning Concept Mapping products and CM itself as a process;

- Critical discussion concerning the use of the inclusion principle, introduced by Novak as a natural consequence of the principle asserting that "... meaningful learning proceeds most easily when new concepts or concept meanings are subsumed under broader, more inclusive concepts, …" (Novak & Gowin, 1984, p. 15.). One of our Discussion Threads is focusing exactly on this topic;

- The discussion on the *Focus Question* cognitive function, included in CmapTools (Cañas et al., 2004) (one more reason to prefer this tool), tightly related with the frame concept specification (the one placed at the top of the cmap) and therefore with the previous problem;

- The issue concerning the choice and added-value of software for constructing and sharing conceptual maps (as opposed to using paper and pencil CM). Our community strongly emphasizes the choice of the IHMC CmapTools software for concept and mind maps. We are moreover "open eyed" towards other potentially more suitable software, for other forms of knowledge representations and/or for primary school students.

All the above mentioned researches and initiatives are aimed to developing models that help the teacher take advantage of concept mapping during classes.

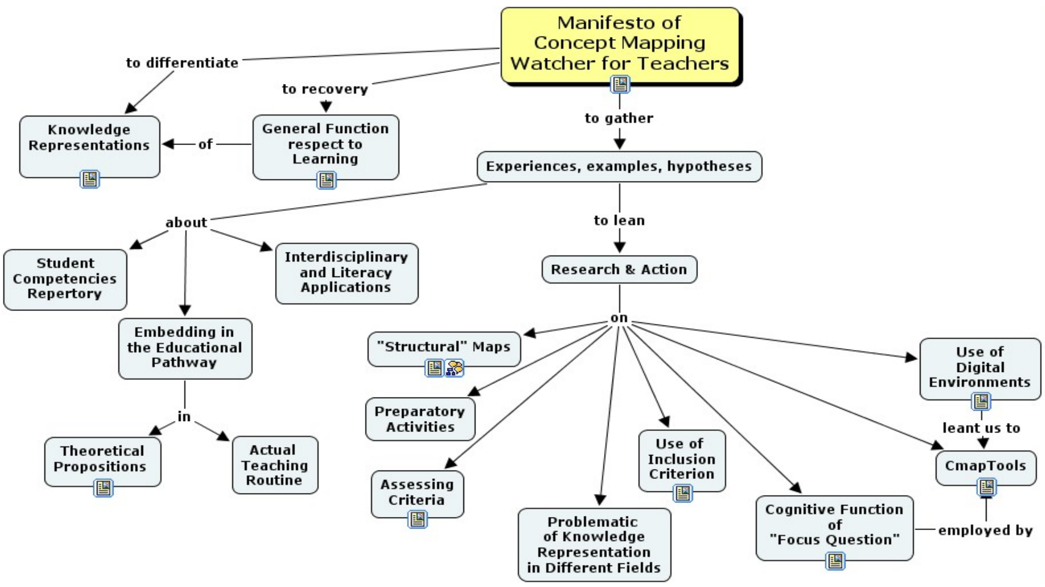

Figure 2. Our Manifesto in cmap format

5 First results

Our website http://map.dschola.it has been contacted over 6000 times, since it began operating. The same server hosts also a CmapServer (Cañas, Hill, Granados, Pérez, & Pérez, 2003) (map.dschola.it (Italy)) collecting about sixty maps and schemas, mostly from associated contributors. All community members initially had some difficulties in classifying, defining, studying and understanding these works, and to regulate and manage the process of collaboration and comparison of ideas to reach agreement and syntheses.

To carry out the sixth objective described above, we have started using email services and recently we have moved to discussion threads, both public and private. We are testing CmapTools collaboration tools for closer interactive work among members, in synchronous and asynchronous modalities.

These adaptation changes are proper for **a *slow*** reflection process of the community as a whole, where the focus is not on the number of contributions gathered, but on how much we gain in awareness of the logical and operative models actually pursued in the published works, their teaching contexts, elaboration modes and actual learning relapses.

We are realizing that concept mapping requires a great cognitive effort, wide theoretical interpretations and constant critical comparisons. The learning process does not consist of an empiric accumulation. It consists indeed of a dynamic and demanding relationship between theory and praxis.

If, on one hand there is a lack of direction and dissemination, on the other hand there is a logical-operating engineered reference model, along with both a large number of experiences apparently implementing (or simplifying) that model, and some experiences critically implementing it.

As far as the evaluation is concerned, we are aware that maps are - above all - an excellent mediation instrument in the educational framework, where the teacher can direct the pupils towards a continuous process of "revision" of the same map, thus being informed on its pupils' pre-competences.

If we assume that concept mapping is a proper language, it is clear that it has a proper "grammar". In order to separate the pedagogical dialogue described above from interferences, it is necessary to concentrate early on the concept mapping syntax, making sure that strategic difficulties – which occur during the proposition coding – don't hide the student's real misconceptions and lack of acquaintances.

For this reason it is necessary both to accurately differentiate propaedeutic activities from those benefiting from the methodology, and develop separate tested schedules, according to our needs. However, strict syntactic rules for concept mapping could cause the same interferences in mediation action. For instance, as far as the inclusion criterion is concerned, Novak underlines how "For different learning segments, the superordinate-subordinate relationships of concepts will change, and we therefore sometimes use the analogy of a rubber sheet for a concept map in which almost any concept can be 'lifted up' to the superordinate position, but still retain a meaningful propositional relationship with other concepts on the map" (Novak & Gowin, ibid. p 16-17). Furthermore, rules state that names and relative pronouns in the linking phrases mustn't be used and many names and attributes cannot be combined in a single conceptual node.

Despite the fact that the above mentioned rules can be regarded as important, they would never prevail over the aim of constructing and gathering new meanings in the truth description.

As far as the Focus Question (FQ) is concerned, we have already specifically defined several ideas and formal criteria.

Firstly, we have gained awareness that the main concept of the FQ itself does not need to coincide with the upper concept on the map, while that map will comply with the inclusion criterion.

In other words, in order to make a survey on a specific issue (the FQ), sometimes it can be suitable to insert the group of necessary concepts in a wider conceptual structure, distinguished from other more knowledge-inclusive related concepts, rather than "pulling up" the focus question-related concepts, by using the inclusion relations in an improper way.

This option will also help the students gain awareness that the knowledge is not made of bricks, but of communicating "organs" linked by "vessels".

Finally, in order to support the reading of concept maps reading (only few people would locate the FQ of a map) we have decided to describe the same Focus Question in an isolated text square. The text square will also account for the author of the map and the educational process beyond it all.

6 Expectations

We have a set of expectations from the community. Among them, that improved technological competences of Italian teachers and improved schools' technological resources will promote the use of concept mapping within the educational context. The effectiveness of this methodology will rely on shared glossary and software, and on educational methods accepted by all educational departments. The sharing of flexible syntax rules for conceptual mapping, and the assessment models (being able to distinguish when our students acquire knowledge in a meaningful way) should also support this methodology.

Our community welcomes new people and supports new institutions, providing "know how" and warranties for good practices in applications on concept mapping.

To give our effort a European dimension of our, we expect to have an English version of our website ready by September 2004.

7 Acknowledgements

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APPLICATIONS OF CONCEPT MAPPING TO UNDERGRADUATE GENERAL EDUCATION SCIENCE COURSES

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Abstract. Constructivism and meaningful learning undergird the use of concept maps. Concept mapping was applied in undergraduate science courses in a small liberal arts college in Boston, Massachusetts, USA. Beginning with the first semester, the instructor used concept maps as advance organizers for lectures and handouts, and students created concept maps as culminating events for the course. In subsequent semesters, student individuals and teams also used concept maps as representations of their thinking about sections of the course; ways to view conceptual structure before and after research; and organizers for a student-created web site. While all applications were useful to some degree, the use of small-group concept mapping was found to particularly enhance use of concept mapping as a tool among the class as a whole and to balance concept mapping with other teaching/learning methods. A student-generated map to organize a class web site linking student research and projects was particularly innovative. While *Inspiration* software was often used in these applications to generate clear and creative concept maps, the new *CmapTools* web site should be valuable in furthering integration of instruction and learning and in enhancing collaborative sharing of concept maps among the educational community.

1 Introduction: Context, Theory, and Practice

Emerson College is a small liberal arts college located in Boston, Massachusetts, USA. The students are particularly strong in communications. The general education requirements for undergraduates include one science course. Key objectives of all the introductory courses taught by Heinze-Fry at Emerson College between 1998 and 2002 were the development of conceptual structure, scientific inquiry skills, problem-solving strategies, and critical thinking (Table 1). In the Environment and Humankind class, an additional objective was the development of an historical perspective viewing the relationship between humans and the environment. Concept mapping was used with a variety of other teaching/learning methods including, among others, data collection on individual use of natural resources (Heinze-Fry, 1993), field work, problem-solving strategies (Heinze-Fry, 1996), forums (NAAEE, 1995), and critical thinking about research articles and web sites (Brooks/Cole web site).

Course/ Objective	Environment and Humankind	Human Body	Personal Nutrition
Concept Development	Concept maps Thought questions Journals	Concept maps Worksheets Short essays Interactive workbook	Concept maps True/False queries about typical misconceptions
Scientific Inquiry	Resource use analyses Field work	Lab reports Field trip reports	Personal scorecards Websites: diet analyses
Problem Solving	Force field analyses Tree diagrams Forum	Case studies	Nutrition action Choosing: “Savvy Diner” tips
Critical Thinking	Research Paper/Project Research article reviews Web site reviews	Research paper Research article reviews	Research article reviews Web site reviews
Historical Perspective	Thought questions		

Table 1. Teaching/ Learning Strategies Used to Meet Educational Objectives in Introductory Heinze-Fry Science Courses at Emerson College1998-2002

What theory drove this practice? The theoretical foundation of this case study rests upon the constructivist (in contrast to positivist) view of education and Ausubel’s theory of meaningful learning (in contrast to rote learning). Our constructed conceptual understanding of a subject helps to shape the world we observe, the questions we ask, our awareness of problems, and the areas of inquiry we wish to address. Therefore, by using concept mapping, the students learn a tool to further expand and examine the framework that guides their perceptions.

Concept maps were created to give visual representation to meaningful learning theory. They represent the conceptual linkages that people have in their minds. In *Learning How to Learn* (1984), Novak provides a generalized concept map illustrating the key features of concept maps. Concepts, or perceived regularities in objects and events, are enclosed in circles. Concepts are connected with lines, and these propositional linkages are labeled with words that describe the relationship between the connected concepts. The map is hierarchical with the most general concepts at the top, connected to progressively more specific concepts and, finally, in some cases, examples of concepts at the bottom of the map. Crosslinks are propositional linkages that connect different sections of the map and indicate integrated thinking. In this study, concept maps were the major instructional strategy utilized in promoting the development of conceptual structure. Over a period of 5 years in 19 classes (9 Environment and Humankind; 6 Human Body, and 4 Personal Nutrition), approximately 500 students created about 2,800 concept maps.

2 Methods of Concept Mapping Applications and Results

Concept mapping was used in a variety of ways by the instructor and the students (Table 2).

Course/ Semester	Environment and Humankind	Human Body	Personal Nutrition
S/98	Lecture; full handouts Culminating event		
F/98	Lecture; full handouts Culminating event		
S/99	Lecture; full handouts Culminating event		
F/99	Lecture; full handouts Culminating event	Lecture; some handouts 8 chapter maps Culminating event	
S/00	Lecture; 14 map-pack 7 team chapter maps Culminating event	Lecture; some handouts 7 chapter maps Culminating event	
F/00	Lecture; 14 map-pack 4 team cluster maps Culminating event	Some handouts 7 chapter maps Culminating event	Lecture; some handouts 7 chapter maps Culminating event
S/01	Lecture; 14 map-pack 5 team cluster maps Culminating event	Some handouts 7 chapter maps Culminating event	Lecture; some handouts 7 chapter maps Culminating event
F/01	Lecture; 14 map-pack 1 individual; 1 team map Culminating event	Some handouts 7 chapter maps Culminating event	Lecture; some handouts 7 chapter maps Culminating event
S/02	Lecture; 14 map-pack 4 individual detail; 4 team maps Pre-/ post-analysis of research Web site organizer Culminating event	Some handouts 7 chapter maps Culminating event	Lecture; some handouts 7 chapter maps Culminating event

Table 2. Concept Mapping Applications in Introductory Heinze-Fry Science Courses at Emerson College1998-2002

In Table 2, the first line in each box indicates how the instructor used concept maps. Generally, concept maps were used as advance organizers for lectures. From Fall, 2000 through Spring, 2002, however, the instructor used publisher-produced *Powerpoint* presentations for their conceptual and photographic visual clarity. Over the course of time, the instructor shifted from giving students full sets of published concept maps to "map-packs" and sample maps to serve as examples for the students. The remaining lines indicate how students created and used concept maps. Concept maps were assigned as part of the "culminating event" of each of the courses. Sometimes these maps were created individually, sometimes in groups. It became clear after the first 4 semesters that the desired quality of culminating concept map was not being created through guided lectures and distribution of the instructor's published maps. Initially, mapping counted only 7% of the total course grade. Ultimately, having students individually or collectively create subunit maps during much of the course and counting the maps as about 1/4 to 1/3 of their total course grade resulted in higher quality culminating maps. This shift in emphasis is indicated in Figure 1.

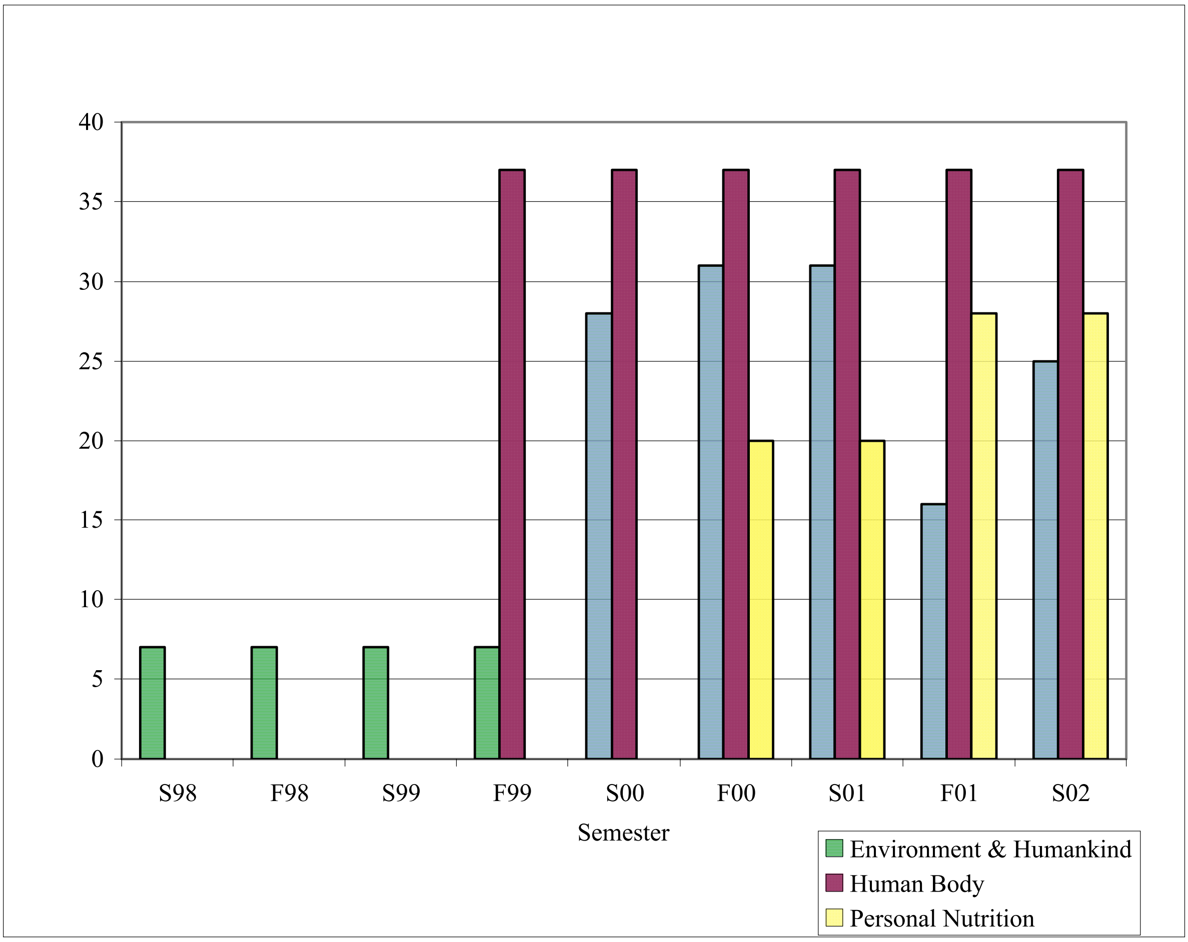

Figure 1. Relative Weight Given to Concept Mapping in Final Grades Over Five Years

In the subsequent semesters, students were given a variety of concept-mapping assignments. In addition to the culminating event, students individually and collectively created maps of individual chapters, parts of chapters, and clusters of chapters. By the last semester, some students used pre- and post-maps to illustrate learning through research projects and one student created a map as a web site organizer showcasing student research papers and projects. Applications of concept mapping were emphasized to varying degrees. Each application varied somewhat in its intent and its outcomes.

2.1 Instructor's Concept Maps as Advance Organizers and Handouts for Lectures

Concept mapping was viewed by the instructor as one of many teaching/learning tools to approach a student body and also as a strategy to integrate other instructional methods. Concept maps on overhead transparencies were used as advance organizers for lectures in all of the courses. In the Environment and Humankind class, the instructor used overview maps found in Tyler Miller's textbook: *Living in the Environment* and in the accompanying *Instructor's Manual.* Specialized chapter maps were used to introduce each new chapter. Throughout the course, new maps were connected to the original overview map. The projected maps provided a good roadmap for lectures. The complexity of these maps, however, often resulted in the projection of small images, which could be difficult to see from the back of the room and could cause "visual overload." Students were given hard copy, on which they could take notes. However, "chunking" to smaller maps to project is probably a better idea. The instructor shifted from giving a complete set of concept maps to giving a 14-map pack to go with lectures (Table 2). Sample concept maps were handed out in the other two courses. Thus, students were encouraged to do more of their own thinking. In the Human Body class, the instructor switched to *PowerPoint* presentations to integrate visuals into lectures. Now *CmapTools* (Cañas et al., 2004) offers capability to integrate any digitally-generated images into a clear conceptual structure.

2.2 Students' Concept Maps as Culminating Events

In an effort to promote integration of the semester's learning experiences, students were asked to create overarching concept maps as a culminating event. Most found this experience challenging and useful. The final concept map stimulated integrative thinking and thought about how to clearly represent ideas. It reduced the multiple and varied experiences of the semester to key understandings and connections. Much effort and individuality of expression went into this exercise. Overview maps were often shared the last day of class. Students and faculty enjoyed seeing these expressions of learning, commitment, and creativity.

Initially, students' maps were created by hand. This process was time-consuming, leaving little time for revision of thinking. Legibility of some maps was also an issue. To allow maps to be more clearly represented and more easily edited, Emerson College bought a site license for *Inspiration* software. There is a "learning curve" in using new software tools. However, with the time invested in learning this new tool, maps generally increased in clarity. Not only was the text clearer, but students were able to reposition concepts to minimize overlapping linkage lines, which can cause visual confusion. Also, color pictoral representations could be added. While some students continued to create concept maps by hand, most found *Inspiration* software to be useful.

Anastasiya and Maria Kobrina, two sisters who worked synergistically, created a map that integrated text (Figure 2A) and photo collages. It was clear that they understood what the key concepts were and linked them together effectively through propositional linkages and hierarchy. (Figure 2B magnifies the central circle of superordinate concepts. Figure 2C magnifies the bottom circle indicating the subordinate concepts for "air resources.") Crosslinks were clear. Color-coding and visuals were used creatively and effectively. Not only did this map showcase the depth of their knowledge and expression, but their work could be a very good learning tool for others approaching the subject.

2.3 Students' Concept Maps to Communicate Understanding of Sections of the Course

In the more highly conceptually oriented chapters of the Human Body and Personal Nutrition classes, students were given frameworks with superordinate concepts that they were to complete with subordinate concepts. Thus, Human Body students mapped all the human body systems. And the Nutrition students mapped all of the macronutrients and micronutrients. The instructor wrote comments, graded, and returned the maps to individual students. Though this approach allowed for identification of insights and errors of individual students, it was very time-consuming for both students and faculty. Some individual maps were transferred to overheads, and, with student permission, the instructor pointed out qualities that made these maps especially meaningful. This instructional strategy somewhat enhanced communication, with students starting to understand clarity, depth of layers, and crosslinking.

In the Environment and Humankind class, where so many other experiences were required, individuals mapped parts of concept clusters, and then put together team "general multi-chapter cluster maps." Teams worked collaboratively with *Inspiration* to create maps (Figure 3), sharing their conceptual knowledge, group process, organizational, and technological skills. When teams presented their results, the class discussed the strengths and weaknesses of their maps. Valued innovations such as color-coding, use of different shapes of polygons to indicate meaning, and the addition of visuals to maps were identified. This experience truly enhanced the diffusion of innovation. As students presented maps to the class, their confidence and communication skills also seemed to improve. It is particularly significant to note the enhanced learning that happens with shared maps among peers. Further, team-mapping reduced the time overload, and concept mapping was kept in balance with other teaching/learning strategies.

2.4 Students' Concept Maps to Demonstrate How Research Changes Conceptual Structure

Students in the Environment and Humankind class were asked to graphically represent the results of their research papers. For this task, some students chose pre- and post- concept maps. While this strategy was not used extensively, its potential as one tool for authentic assessment was demonstrated.

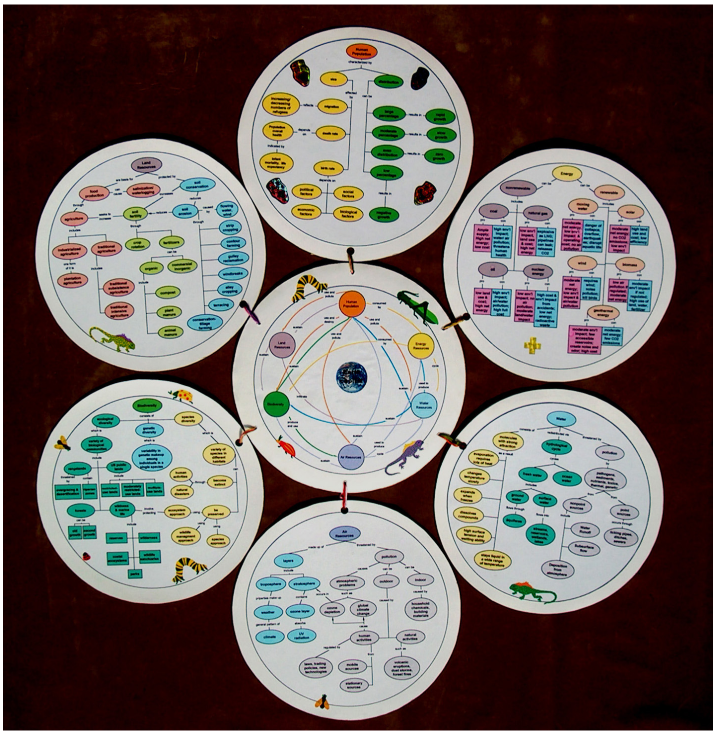

Figure 2A. Earth Capital Overview

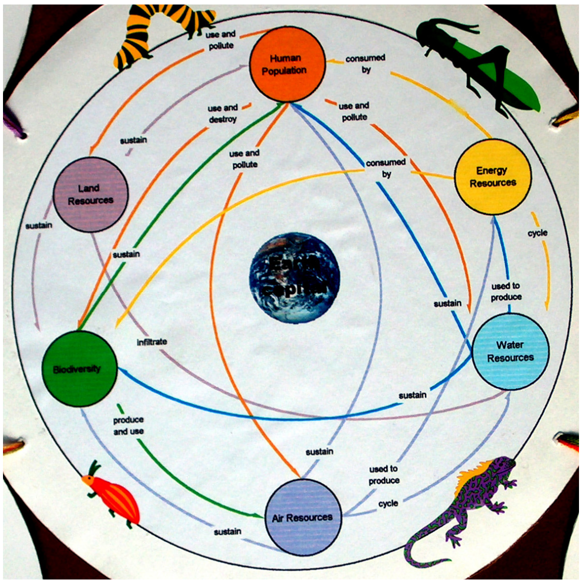

Figure 2B. Earth Capital: Superordinate Concepts in Center Circle

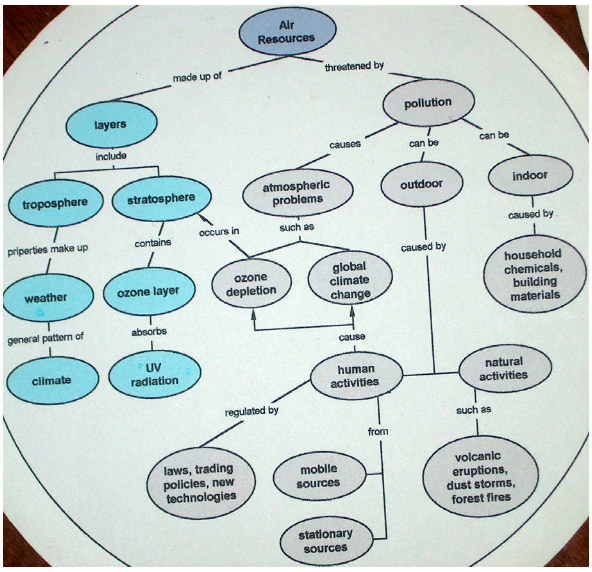

Figure 2C. Earth Capital: Subordinate Concepts in Bottom Circle

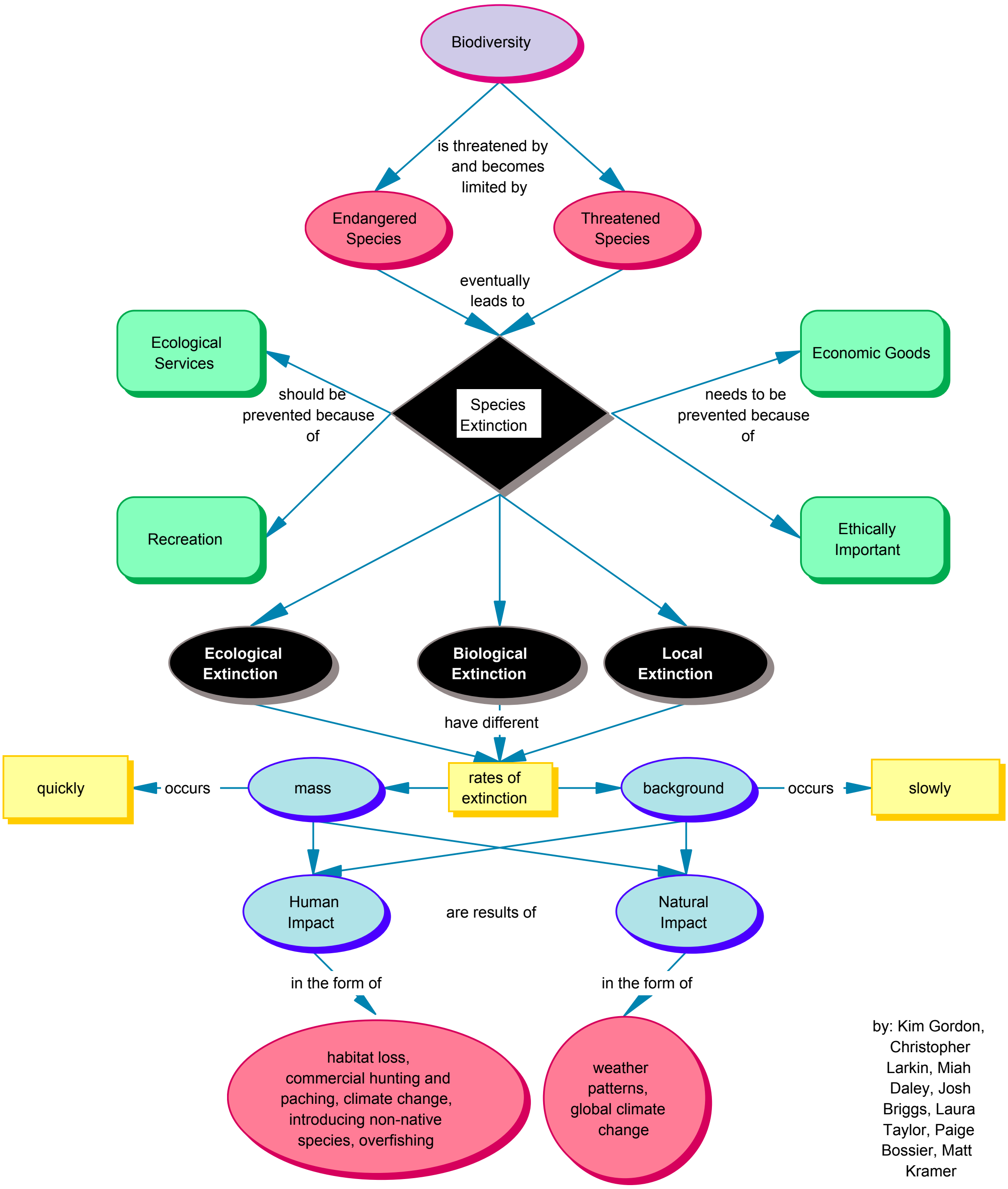

Figure 3. Team-generated concept map of "Biodiversity."

2.5 A Student's Concept Map as an Organizer for a Class Web Site

The most recent innovation using concept maps was employed by a group of students who created a web site to showcase students' research papers and projects. In a "homepage" window, Justin Baum created an interface offering an option to click on key "concept clusters" under which were categorized students' research papers/projects. In addition, there was a "button" to view "concept maps." This button linked to Paul Maiorana's one-window concept map, which was quite simple and similar to the superordinate concepts in Figure 2B. Each of the key concepts was hyperlinked, and a click led to a more detailed concept map similar to Figure 2C. In the future, *CmapTools* would allow those two functions to be seamlessly integrated, and the students' work would actually be linked to the overview map. Research papers were illustrated with a variety of graphic organizers: pre- and post- concept maps; a vee map; and a concise historical representation of the change in a debate over time. This was a class willing to choose research topics and experiment with different strategies of learning and expression. The class web site was presented at the Cybercafe at the North American Association for Environmental Education Conference in Boston in 2002.

This particular class brought concept mapping forward as a way to integrate a class of highly creative individuals and show how their individual research and projects contributed to the understanding of the whole class. Concept mapping was in context and served to link a variety of learning experiences and their visual representations. For today's computer-literate student body, the experience of this class points toward concept mapping as a tool to integrate the learning experience of a group in a web-based environment, which can be shared with the larger human community.

3 Conclusions from Applications of Concept Mapping in Introductory Science Classes

- This particular instructor had worked for years to create concept maps for the textbook used in her course. Therefore, it was meaningful to her to use these maps as roadmaps for the course and ensure that key understandings were emphasized. The written visuals reinforced the verbal direct instruction. However, the instructor concluded that in order to encourage students to create their own maps, distribution of a sample map-pack of published concept maps was preferable to a full set.
- Use of concept mapping as a learning tool was facilitated by an instructor and students who truly wished to clarify and communicate their thinking. Some students responded very favorably and wondered, "Why haven't we been taught how to do this before?" They were so relieved to be freed from multiple choice testing. Some students, particularly those who were good at memorization, did not appreciate the time it took to represent their thinking in concept maps.
- Constraints and concerns about concept maps were expressed by both students and administrators. Student concerns included the amount of time it took to create maps, the "spaghetti-type confusion" of some maps with many overlapping propositional linkages, the visual overload of maps with too many concepts, and a preference for "straight-line thinking." The administration expressed concern that a variety of appropriate teaching/learning strategies be used. The use of concept mapping software, particularly *Inspiration* in small-group contexts, seemed to alleviate many of these concerns as well as increase diffusion of innovations and preferred strategies. Concept maps counting about 1/4 to 1/3 of the final grade seemed appropriate to produce high-quality maps and balance concept mapping with other learning strategies.
- While concept maps presented by the instructor during lecture and individually produced student concept maps were effective tools, the more innovative applications that grew from this case study were: (1) small-group concept mapping and sharing with the class; (2) concept mapping as a culminating event; and (3) concept mapping to integrate students' research and projects on a class web site.
- The use of a concept map as a gateway to a class web site showcasing student work integrated a variety of learning strategies. It facilitated communication within the class and within the larger community. *CmapTools* (http://cmap.ihmc.us/) with web-based sharing and editing of concept maps offers an even stronger collaborative tool for the future.

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Pamplona, Spain 2004

EXPERIENCIA CON EL USO DE MAPAS CONCEPTUALES COMO ESTRATEGIA DE ENSEÑANZA EN UN CURSO DE INGENIERÍA DEL CONOCIMIENTO

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Abstract. Los mapas conceptuales se han utilizado en diversas formas como estrategia pedagógica. En el caso particular de la Ingeniería del Conocimiento éstos han sido utilizados como un método de representación de un conocimiento en un dominio específico para la construcción de Sistemas Basados en el Conocimiento, pero no como una herramienta de enseñanza y aprendizaje de los conceptos que la conforman. De esta forma se planteó la introducción de los mapas como estrategia de aprendizaje y como tema propio de la asignatura Ingeniería del Conocimiento en el pregrado de Ingeniería de Sistemas, en donde además de trabajar los temas apropiados, se fijó como objetivo verificar la efectividad de utilizar los mapas conceptuales como técnica pedagógica.
El propósito de este artículo es aplicar los mapas conceptuales no sólo como técnica de representación del conocimiento sino como estrategia pedagógica para la enseñanza de los principios básicos de la Ingeniería del Conocimiento. Se presentan las diversas formas en que se utilizaron los mapas conceptuales en la asignatura Ingeniería del Conocimiento. Adicionalmente, se incluyen los resultados de evaluación de cada una de las formas de aplicación de los mapas, tanto desde el punto de vista de la profesora como de los estudiantes.

1 Introducción

En la asignatura Ingeniería del Conocimiento (ST074) de la carrera Ingeniería de Sistemas de la Universidad EAFIT se utilizaron los mapas conceptuales como estrategia de enseñanza en diversas formas: como organizador previo, como técnica de representación de un conocimiento nuevo, como estrategia de evaluación, como herramienta para aprender mapas conceptuales y como técnica para reflejar un conocimiento nuevo. Esta experiencia se realizó durante el semestre 2003-2. A continuación se presentan los objetivos de esta asignatura, para comprender mejor la descripción de esta experiencia:

- Comprender los propósitos y el alcance de la Ingeniería del Conocimiento (IC) a través de artículos, videos y del trabajo que se lleve a cabo en la clase presencial para que el estudiante la pueda utilizar en su actividad profesional futura.
- Reconocer los modelos para la adquisición y representación del conocimiento humano basado en computadora presentados en clase y que serán evaluados en los exámenes y prácticas, para que los diferencien entre sí y vean la utilidad real de cada uno de ellos.
- Comprender la arquitectura y los componentes de un sistema basado en el conocimiento de primera generación presentada en clase, consultada en los textos de referencia y aplicada en el sistema práctico que el estudiante debe desarrollar.
- Aplicar la técnica de representación del conocimiento de mapas conceptúales para manifestar y explicar los conceptos fundamentales de un área de la Inteligencia Artificial."(Henao, 2003).

Dentro de esta materia se estudian diferentes técnicas de representación, entre las cuales están los Mapas Conceptuales. Incluso, así se aplique o no la técnica de mapas conceptuales como estrategia de enseñanza y aprendizaje, este tema es parte del contenido de la materia.

La mayoría de los estudiantes expuestos a este caso, no habían tenido experiencia previa en la elaboración de mapas conceptuales por lo que el proceso durante el semestre y los resultados obtenidos, fueron muy buenos, tanto desde el punto de vista de logro de objetivos de la materia como desde la visión de la utilidad de esta estrategia. Para conocer el impacto sobre los estudiantes se diseñó un instrumento de consulta el cual fue aplicado a los 43 estudiantes matriculados en la materia (Zea, C., Atuesta, M. R., Henao, M., Hernández, P. 2004). De esto es de lo que se trata este artículo, estructurado de la siguiente forma: la sección 2 presenta en forma más detallada los objetivos del curso de Ingeniería del Conocimiento. En la sección 3 se presentan las diversas formas como se utilizaron los mapas conceptuales, tanto por parte de la profesora como de los estudiantes. Por último se presentan las conclusiones, trabajos futuros y las referencias pertinentes.

2 Descripción de la Experiencia

Dentro de la psicología cognoscitiva se han desarrollado procedimientos aplicados, que consideran que afectan la manera en que un estudiante aborda el proceso de apropiación o asimilación del conocimiento, entre ellos se encuentran los llamados "Mapas Conceptuales". Estos son una estrategia de aprendizaje que, desde la perspectiva cognoscitiva fueron diseñados por Novak y Gowin (1984) y que pretenden servir de herramienta metodológica en el proceso de aprendizaje para representar el conocimiento y que pueda lograrse un aprendizaje significativo, acorde con la teoría de Ausubel (Ausubel, D., Novak, J., Hanesian, H. 1983). Esta herramienta como técnica para abordar el conocimiento, posibilita tanto la organización del objeto de aprendizaje como el hacer explicita la estructura cognocitiva previa del aprendiz respecto a un tema como objeto de estudio. Es por esto que en esta experiencia se utilizaron los mapas con diversos propósitos, cada uno con unas características, objetivos y logros particulares. A continuación se describe detalladamente cada una de aplicaciones y se anexan algunos de los mapas construidos como resultado de ellas.

2.1 Como organizador previo

El primer uso que se le dio a los mapas conceptuales es responsabilidad de la profesora y consiste en organizar el contenido de la materia como un "Modelo de Conocimiento". El mapa conceptual *Ingeniería del Conocimiento* es el producto de esta aplicación. En él, los conceptos son los temas y conceptos básicos de la materia y las relaciones son las conexiones conceptuales que deben existir entre ellos. El mapa responde a la pregunta *¿Cuáles son los temas básicos del curso Ingeniería del Conocimiento*? Se puede observar que en los conceptos Inteligencia Artificial, Sistemas Basados en el Conocimiento y Mapas Conceptuales se incluye el llamado a otros mapas fundamentales para complementar la temática. En la figura 1 se puede apreciar este mapa.

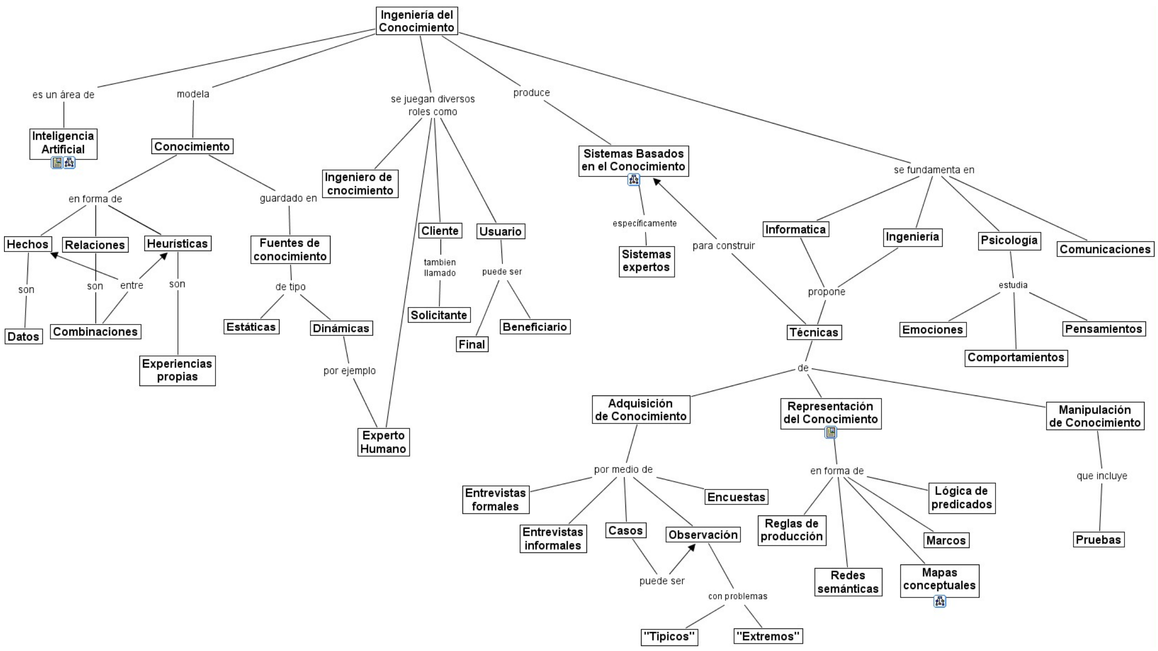

Figura 1. Mapa Conceptual Ingeniería del Conocimiento

De esta forma, este conjunto de mapas se utiliza para explicar, en la primera sesión de trabajo, el contenido de la materia con el objetivo de presentar una idea clara sobre él y para familiarizar a los estudiantes con los conceptos, temas y palabras claves en el dominio de la Ingeniería del Conocimiento.

Esto, de acuerdo con Brunner (1990) permite que el estudiante aprenda la "estructura de la disciplina". Esta estrategia fue evaluada al finalizar esa primera clase con el fin de tomar acciones correctivas y también se evaluó al final del semestre, cuyos resultados fueron muy positivos y se pueden observar en la tabla 1:

PREGUNTAS	Mucho	Poco	Nada
¿El mapa conceptual presentado por la profesora al inicio del curso, le permitió tener una visión global del mismo?	94%	6%	0%
¿El mapa conceptual presentado le permitió ver la relación entre las diferentes temáticas del curso?	94%	6%	0%
¿Al ver el mapa conceptual sobre los temas del curso se modificó su idea previa del éste?	44%	44%	12%
	Positiva		**Negativa**
En caso de que su idea previa haya sido modificada, dicha modificación fue:	96%		4%
	Si		**No**
¿Le gustaría que para la presentación de los contenidos de los cursos se usara la estrategia mapas conceptuales?	85%		15%

Tabla 1: Evaluación al final de la materia, relacionada con el mapa de organizador previo

2.2 Como técnica de representación de un conocimiento nuevo, presentado previamente en clase

El tema que se eligió para hacer el primer mapa conceptual por parte de los estudiantes fue *El Cerebro Humano*. Previamente se dedicaron cuatro horas de clase a la presentación de este tópico, haciendo uso de un video especializado y de charlas magistrales por parte de conocedores del tema. De estas charlas se tiene como resultado un material que se puso a disposición de los estudiantes en la herramienta digital que permite tener un campus bimodal en la Universidad EAFIT y que le provee a la comunidad universitaria un entorno educativo que combina los aspectos positivos de la educación presencial y la utilización de las tecnologías telemáticas, llamado EAFIT Interactiva.

La estrategia de aplicación de los mapas conceptuales, en este caso en particular, consiste en una actividad en la que los estudiantes deben representar el conocimiento presentado previamente en clase. Para esto no se dieron pautas específicas en cuanto al alcance o enfoque del tema, de forma tal que el estudiante es libre de hacer la pregunta y definir los conceptos y relaciones que considere más pertinentes para reflejar en el mapa. Tampoco se utilizó ninguna herramienta informática para representar el mapa, se quiere que el estudiante primero se familiarice con la técnica de representación y que haga el mapa en papel. De esta forma, los estudiantes reflejan lo que saben y entiende del Cerebro Humano en sus aspectos funcionales o anatómicos. La evaluación posterior de la actividad se orientó a la corrección de los conceptos elegidos y sus relaciones.

La mayoría de los estudiantes expuestos a este caso no habían tenido experiencia previa en la elaboración de mapas conceptuales, por lo cual, se les dio un documento de trabajo que explicaba en forma general cómo construir un mapa conceptual y su objetivo. También, se presentaron en clase algunos mapas conceptuales a manera de ejemplos concretos.

Los resultados con esta experiencia no fueron muy buenos, pues la mayoría de los mapas conceptuales elaborados por los estudiantes presentaron errores, bien conceptuales o bien en la elaboración de las conexiones. Después de hacer el análisis se concluye que los factores que influyeron principalmente en este resultado fueron los siguientes:

- Falta de experiencia en la construcción de mapas conceptuales
- Falta de práctica en el desarrollo de representaciones gráficas.
- Complejidad del tema, *el Cerebro*, pues la mayoría de los estudiantes desconocen los detalles de éste.

Es interesante resaltar que los estudiantes reportaron esta actividad como positiva, lo cual indica que a pesar de las dificultades para construir los mapas conceptuales, lograron mantenerse motivados. La información mostrada en la tabla 2, evidencia esta apreciación.

PREGUNTAS	Positiva	Negativa
Al desarrollar el mapa conceptual sobre el Cerebro, su experiencia puede considerarse como:	96%	4%

	Mucho	Poco	Nada
¿Elaborar este mapa conceptual le sirvió para conocer más sobre el Cerebro?	94%	4%	2%
¿Cree usted que puede reflejar sus conocimientos en algún tema en un mapa conceptual?	94%	6%	0%
¿Cree que al hacer un mapa conceptual, puede evaluar lo que usted sabe del tema?	65%	30%	5%

Tabla 2: Evaluación del mapa del Cerebro construido por los estudiantes

A pesar de esto, el ejercicio se toma como una primera experiencia que sirve tanto para el docente como para los estudiantes. Para el primero, para refinar la estrategia de uso de los mapas, y para los segundos porque de esta forma pueden recibir una retroalimentación más detallada acerca de cómo construir mapas conceptuales o cuestiones propias del tema representado.

2.3 Como estrategia de evaluación de un conocimiento específico

Al concluir la semana quinta del desarrollo del curso, se creía que ya se habían desarrollado en buen grado, las habilidades para construir mapas conceptuales, por tanto se decidió aplicar una nueva forma para utilizarlos:

En la primera evaluación parcial, se incluye un punto para la construcción de un mapa conceptual, con valor de 2 sobre 5. Se pretende medir el nivel de conocimiento y la claridad alcanzada en cada uno de los temas estudiados hasta el momento. Las indicaciones que se dan para esta actividad son las siguientes:

1. Responder a la pregunta ¿Cuáles son los objetivos de la Inteligencia Artificial? (tema trascendental en el curso)
2. Incluir como mínimo 10 conceptos.
3. Los criterios de evaluación del mapa se basan en el cumplimiento de los numerales 1 y 2 y en que las relaciones que se establezcan, debe ser correctas.

De acuerdo con las apreciaciones de la profesora, los mapas conceptuales construidos por los estudiantes durante esta evaluación permitieron observar que:

- Los estudiantes no saben responder a la pregunta planteada para el mapa. Es decir, se presentan fallas en la comprensión de los temas propios de la materia.
- Se presentan muchos errores en la selección de los conceptos que se incluyen en los mapas.
- Se tienen errores en las relaciones establecidas entre los conceptos incluidos.
- Se manifiestan serias dificultades en la construcción de proposiciones, pues para tener una oración coherente es necesario leer entre más de 2 conceptos.

Es decir, que se presentan errores relacionados con el contenido de la materia y también con la estrategia de mapas conceptuales propiamente dicha.

2.4 Como herramienta para aprender la técnica de representación del conocimiento a través de mapas conceptuales

En este caso, se utilizaron los mapas conceptuales como herramienta para aprender la técnica de modelado de conocimiento por medio de mapas conceptuales, pues durante el curso hay un tema fundamental que es el Proceso de Representación del Conocimiento para hacer Sistemas Basados en el Conocimiento. Dentro de este proceso se estudian diferentes técnicas de representación, entre las cuales están los Mapas Conceptuales. Incluso, así se aplique o no la técnica de mapas conceptuales como estrategia de enseñanza y aprendizaje, este tema es parte del contenido de la materia.

El objetivo con este ejercicio es que los estudiantes representen en forma gráfica, por medio de un mapa conceptual, el conocimiento que está expresado en forma textual, para que se ejerciten en la elaboración de mapas conceptuales. El texto expresa la definición de "concepto". De esta forma, para poder representarlo en forma gráfica, es necesario comprenderlo, extrayendo la información relevante y estableciendo las mejores relaciones.

La representación de lo leído en el texto en el mapa conceptual, corroboró las apreciaciones de los estudiantes en relación con la actividad anterior sobre "el Cerebro", en cuanto a la experiencia de construir un mapa conceptual. Es decir, que con el ejercicio se puede conocer más acerca del tema y que es un ejercicio que les motiva el trabajo.

Una vez realizado los mapas conceptuales, se distribuyen entre los mismos estudiante, para que cada uno tenga un mapa diferente al suyo, con el objetivo de que lo evalúen. El criterio fundamental de la evaluación es: "lo que está reflejado en el mapa debe expresar lo mismo que hay en el texto escrito" y por lo tanto, a través del mapa conceptual se responde la pregunta ¿qué es un Concepto? (Tema del mapa).

Después se le pregunta a cada uno *¿En qué aspectos se ha fijado para saber si el mapa es correcto?* Las respuestas de los estudiantes son:

- Debe responder a la pregunta inicialmente planteada
- Que se pueda establecer una frase correcta entre los conceptos
- Que se ajustara a lo que ambos sabían del tema
- Se pudiera leer, tuviera orden y se entendieran todos los conceptos expuestos

Este ejercicio es muy enriquecedor porque permite que los estudiantes:

- Confronten sus conocimientos acerca de mapas conceptuales
- Confronten la interpretación del texto frente a la de los compañeros
- Identifiquen errores conceptuales sobre el tema tratado

Además, a través de la discusión grupal que se originó después del ejercicio, surgieron pautas o criterios de evaluación para los mapas conceptuales, que fueron posteriormente aplicados para evaluar otros mapas conceptuales.

2.5 Como técnica para reflejar el conocimiento adquirido de un dominio

Como uno de los objetivos que se tenía era la utilización de la técnica de los mapas conceptuales en la asignatura Ingeniería del Conocimiento, es necesario verificar si realmente el uso de mapas conceptuales puede incluirse como parte de las estrategias didácticas diseñadas, y más especialmente para lograr el aprendizaje de los estudiantes, se plantea hacer un ejercicio de carácter individual, una vez que se ha desarrollado un 80% del contenido del curso.

El ejercicio consiste en dar a cada uno de los estudiantes el mapa conceptual del curso Ingeniería del Conocimiento (el mapa elaborado por la profesora como organizador del curso – Figura 1) para que cada uno lo amplíe de acuerdo con los conocimientos adquiridos durante éste. Así, el estudiante debe representar la visión propia y el conocimiento que ya ha adquirido de la materia.

De esta forma, el profesor pretende determinar los conocimientos adquiridos por el estudiante, en relación con la técnica y con la temática de la materia. La evaluación del mapa se hace teniendo en cuenta que todo lo que esté reflejado en él es correcto bajo la técnica de los mapas conceptuales y bajo la teoría de la Ingeniería del Conocimiento, no se hace desde el punto de vista de la cantidad de conceptos y relaciones que el estudiante adiciona. El ejercicio es voluntario.

La actividad permite crear un banco de mapas acerca de la materia Ingeniería del Conocimiento. Algunos de los mapas son muy "pobres" y otros muy "ricos", entendiendo por mapas pobres aquellos en donde el estudiante no ha aportado mayor cosa al mapa original, y por mapa muy rico aquel en donde se manifiesta un esfuerzo por parte del estudiante para crecer apropiadamente el mapa original.

En general, la mayoría de los estudiantes tenía los conocimientos necesarios para complementar el mapa, lo cual evidencia que se lograron aprendizajes importantes durante el curso. Adicionalmente, la profesora consideró que los resultados generales de la actividad de uso de los mapas conceptuales como instrumento para evaluar el conocimiento de un estudiante sobre un tema en particular fueron muy positivos, pues se demostró:

- El gran interés que la mayoría de los estudiantes puso en el trabajo.

- Los estudiantes establecieron relaciones con conceptos previos, básicos para la comprensión del tema nuevo.

Sobre esta actividad se preguntó a los estudiantes lo siguiente:

PREGUNTAS	Mucho	Poco	Nada
¿Sintió que podía complementar el mapa del curso?	62%	24%	14%
¿Sintió que con lo que usted sabía del tema era suficiente para ampliarlo?	21%	56%	23%
¿Sintió era necesario buscar otras fuentes de información para completarlo?	79%	21%	0%

Tabla 3: Opinión de los estudiantes en relación con la ampliación del mapa de Ingeniería del Conocimiento

2.6 Como técnica de representación del conocimiento de un dominio completamente nuevo para el estudiante. Esta estrategia fue para un grupo de estudiantes

Los estudiantes esta vez trabajaron en parejas, cada una con un tema en particular relacionado con la Inteligencia Artificial. Los temas para todos los grupos fueron diferentes y no habían sido previamente estudiados por ellos, así que se requería que cada grupo hiciera una indagación sobre el tema, lo estudiara, lo tradujera a sus términos y luego representara ese nuevo conocimiento en mapas conceptuales a manera de síntesis del trabajo realizado (ver figura 2). Adicionalmente, éste tenía que ser sustentado ante todo el grupo, con el propósito de socializar los diferentes temas trabajados.

Como esta actividad se realizó en la parte final del curso y dado que los estudiantes ya manejaban la técnica de los mapas conceptuales, se decidió utilizar la herramienta CmapTools para construir los mapas. Cada grupo era responsable de aprender el manejo de la herramienta. Los estudiantes entregaban los mapas en formato cmap. La mayoría decidió hacer la presentación final del trabajo y la sustentación, siguiendo los mapas con ayuda de la herramienta informática.

En esta actividad los mapas conceptuales son utilizados como *organizadores de información* en primera instancia y como *síntesis de los conocimientos adquiridos* por los estudiantes en su investigación. Esta actividad fue evaluada por la profesora como exitosa, en la medida en que:

- Los trabajos y los mapas como resultado final de la actividad quedaron muy completos,
- Los estudiantes hicieron uso de la herramienta computacional CmapTools para construir y perfeccionar los mapas, lo que les facilitó el trabajo final de representación.
- Se incluyeron recursos adicionales a los conceptos tratados en el mapa, haciendo uso de las funcionalidades de la herramienta computacional CmapTools, permitiendo ampliar la temática.
- Durante la sustentación oral de sus trabajos demostraron que habían adquirido el conocimiento, empezando a manejar la terminología básica y propia de cada una de las temáticas.

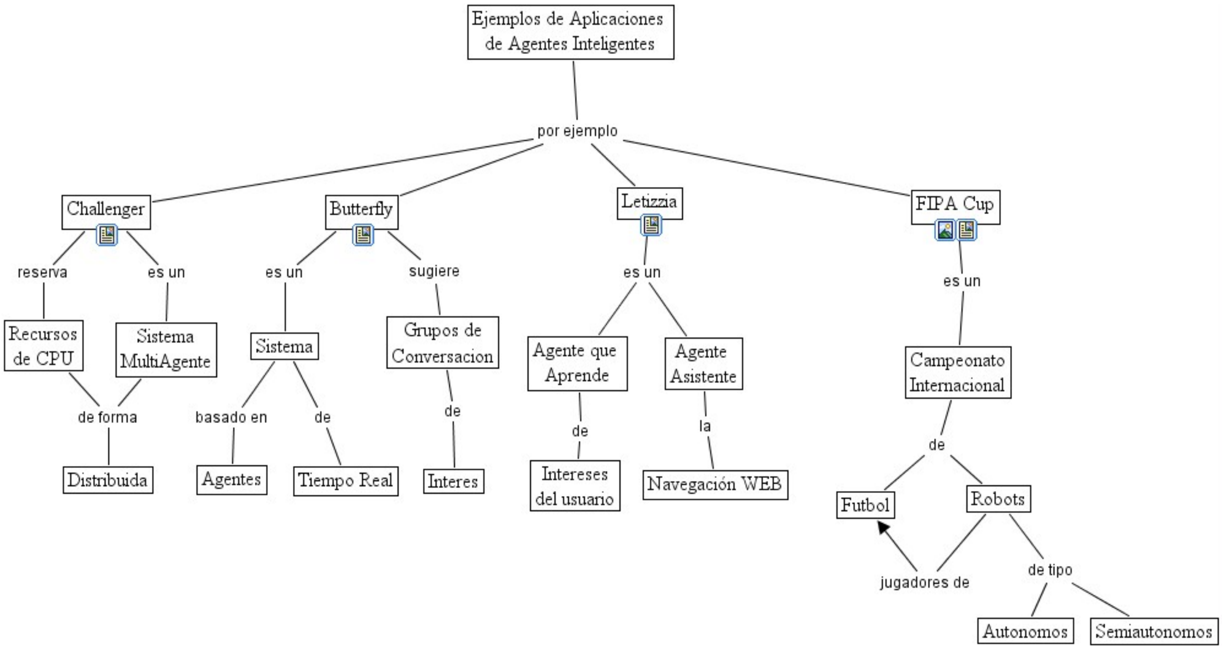

Figura 2. Mapa Conceptual realizado por un estudiante en un tema nuevo para él

Como última indagación, a los estudiantes se les preguntó si volverían a usar mapas conceptuales, a lo que más del 85% de los estudiantes respondió de manera positiva. Las razones que dieron para pensar en continuar con el uso de los mapas conceptuales fueron, entre otras:

- Los mapas conceptuales sirven para transmitir a otras personas conceptos claves de un tema. Además sirven como organizadores de temas para facilitar el estudio de ellos.
- Sirven para hacer la programación de tareas y representación de temas
- Permiten representar y organizar conocimiento
- Para estudiar, para reflejar el contenido visto en una materia y resumir un documento.
- Estudiar temas nuevos mediante mapas conceptuales logra sintetizar conceptos mentales de manera que resulta fácil retomarlos y para estudiar temas ya conocidos pues obliga a confrontar el conocimiento ya adquirido.

Los usuarios que emplearon la herramienta CmapTools para elaborar este tipo de mapas (representación de conocimiento previo), la percibieron como "amigable" de fácil manejo y aplicación. Además, al utilizarla pudieron completar y soportar cada concepto con múltiples recursos, haciendo la representación mucho más dinámica y enriquecedora.

3 Resumen

Como parte del análisis que se realizó durante la investigación en la que estaba enmarcada esta experiencia, sobre las posibilidades de uso de los mapas conceptuales en el marco de los ambientes de aprendizaje, se concluye que estos pueden ser utilizados en las diversas etapas del proceso de aprendizaje (construcción de conocimiento), y con aplicaciones muy variadas (Zea, C., Atuesta, M. R., Henao, M., Hernández, P. 2004). Durante la fase inicial del proceso de aprendizaje, los mapas pueden ser usados como orientadores del proceso, como organizadores de contenido, como contenido nuevo y su relación con conocimientos previos o anteriores y como conocimiento experto (en casos donde se tiene acceso a conocimiento científico sin mediación interpretativa) entre otros.

Durante la etapa de desarrollo del proceso de aprendizaje, los estudiantes pueden hacer la representación de los nuevos conceptos apropiados y su relación con los ya conocidos, observando una mejora en los niveles de comprensión de un concepto o tema. Desde el docente, el análisis de cada uno de los mapas construidos por el estudiante, le facilita la evaluación del proceso y la identificación de los logros en cada caso, visualizando tanto los errores conceptuales como los vacíos en temas específicos que pueda tener el estudiante y, a partir del desarrollo de los temas, el establecimiento de conceptos claves y sus relaciones.

Durante la etapa final de un proceso de enseñanza aprendizaje (finalización de un curso específico), los mapas se convierten en una representación gráfica a manera de síntesis de los conceptos, significados y relaciones de los contenidos curriculares aprendidos durante el proceso por el estudiante, y muestra lo que aun le falta por aprender.

De esta forma, se ha mostrado en este artículo, que el uso de los mapas conceptuales en el aula de clase genera múltiples ventajas, pero manejando apropiadamente la estrategia de representación. Aunque la herramienta informática para representar mapas es excelente y fácil de manejar, es importante entrenarse primero en la construcción de los mapas antes de comenzar con la utilización de la herramienta, pues de esta forma se valora más el tratamiento apropiado de la técnica de los mapas y el manejo correcto del conocimiento del dominio. Y, una vez que se ha logrado dominar la estrategia, utilizar CmapTools enriquece más el aprendizaje del dominio dadas las posibilidades que la herramienta ofrece, por ejemplo: adicionar recursos de imágenes, textos, videos, poner anotaciones o comentario, entre otras cosas.

Después de esta experiencia se ha decidido continuar con la aplicación de los mapas en la materia de Ingeniería del Conocimiento, comenzar a introducirlos en otras para hacer un análisis formal en donde se compare el rendimiento, los resultados de los alumnos que utilizaron los mapas conceptuales como estrategia de aprendizaje de los contenidos del curso frente a los resultados obtenidos en estudiantes que no los utilizaron.

4 Agradecimientos

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SUPPORT FOR AND RESISTANCE TO A CONCEPT MAPPING ASSIGNMENT IN A PHARMACY COMMUNICATIONS COURSE

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Abstract. A concept mapping assignment was developed for pharmacy students that emphasizes meaningful learning and discourages rote memorization of communications course material with the intention to improve student retention of pharmacy communications information. Students in small groups work to create a concept map that demonstrates their understanding of major concepts taught in the course and their interrelationships. Support for this work came from faculty in other disciplines and institutions, but resistance to the assignment came from students, faculty peers, and administrators. Student perceptions of the assignment were sought and are reported here. Incorporating a concept map assignment into an existing course requires a significant investment for instructors. The reward for faculty is that students learn to understand abstract material and grapple with conceptual meanings so that they are challenged to move beyond rote memorization to meaningful learning. However, given the resistance, a wise faculty member choosing to use concept mapping as an assignment would also educate his/her peers and administration about the value of visual learning.

1 Introduction

Encouraging students to achieve long-term integration of knowledge is a challenge to all faculty teaching in higher education. Many students have learned to rely on rote memorization in their early college years to obtain the 'right' answers. This method may have been successful for completing prerequisite courses, but in a healthcare profession such as pharmacy knowledge must be retained for application in complex practice settings in which ill-defined problems are frequently encountered. Professionals must therefore achieve a sophisticated understanding of the conceptual tools within their discipline. Novak comments that students can be tenacious in their preference for rote memorization because of previous success with the method and because memorization requires a smaller investment of mental energy than learning to fully understand course material (Novak, 2003). Over-reliance on rote memorization is counter-productive to retention of meaningful knowledge, and knowledge gained this way requires intense effort to maintain and constant reinforcement (Donald, 2002; Novak, 1998; Trepagnier, 2002).

Instructors are able to influence student choices of how to learn with their decisions regarding how material is presented in class, the creation of exercises that engage students with course material, and how student learning is assessed. As a graphic knowledge representation tool, a concept map enables students to diagram their understanding of key ideas in a topic area and to demonstrate their conceptions of the relationships among them (Novak, 1998; 1984). Students are often able to articulate key concepts within course material, but they may be unclear about the relationships among them and their relative importance (Trepagnier, 2002). A concept map assignment can help students listen for meaning in class, assist students in taking more effective notes, and promote conceptual learning.

The *Communications in Pharmacy Practice* course at the VCU School of Pharmacy is a two-credit course that is currently offered in the first semester of the Doctor of Pharmacy program. The content 1) addresses communication skills employed in pharmacy practice with an emphasis on patient counseling and education, 2) explores communicating with diverse populations including geriatric, mentally ill, and disabled patients, and 3) provides instruction about low health literacy and cultural competence. A concept mapping assignment was introduced because the pre-existing course structure did not appear to encourage students to engage with the material and students were not retaining information they need to successfully engage in the culminating experiential program and in practice after graduation.

Introducing a concept mapping assignment is not without its difficulties, however, and it was met with resistance from several quarters: the students, other faculty, and administration. Students were resistant because concept mapping requires students to engage with course material in meaningful ways, and this requires substantive effort. Faculty peers were dubious because they were unfamiliar with the concept mapping process, and suspicious that the assignment might consume excessive time that students might have invested in studying for other courses. Administrators were the recipients of student complaints, and were also unfamiliar with the value of concept mapping.

2 The Assignment

Concept mapping was selected as an active learning process that involves students in meaningful learning because the process engages complex cognitive structures within the brain. Meaningful learning refers to the process of acquisition of new information by an individual and its interrelationship with relevant knowledge mental structures (Novak, 2003; Trepagnier, 2002; Novak, 1998). The learning tends to be long lasting because the new knowledge is related to and integrated within a person's existing knowledge structure (Novak, 1998). Cognitive learning theory indicates that the brain learns most effectively by relating new experiences and knowledge to prior knowledge, and that meaningful learning requires deliberate effort to link new knowledge with higher-order, more inclusive concepts in a person's cognitive structure (Trepagnier, 2002; Heit, 1997; Roth & Roychoudhury, 1993; Novak, 1984).

Past research indicates that conceptual mapping has clearly demonstrated its value in helping students learn in the natural sciences. Trepagnier (2002) argues that requiring students to create concept maps is especially useful in teaching abstract, conceptual topics in which there may be multiple ways to interpret the interesting and abstract relationships between concepts. In an interdisciplinary study of intellectual development of postgraduate students, Donald (2002) found that the sciences tend to teach more concepts within a single course than the social sciences, but that the meanings of these concepts tend to be explicit and specific. In the social sciences, as much as 90 percent of subject matter may be abstract. Learning about pharmacy communications requires students to engage with abstract notions of the social, psychological and behavioral aspects of pharmacy care.

An introductory class session of the course was devoted to explaining the process of concept mapping and the purposes of the assignment. A detailed presentation explained the structure of concept maps and their relevance to education and then provided opportunities for questions. Students were engaged in an exercise in which they practiced creating a simple concept map of their existing knowledge of pharmacy communications at the outset of the course. Students also received handouts that 1) explained the assignment and concept mapping, 2) included a concept map that demonstrated the general structure, 3) provided an example of a relevant concept map, and 4) specified scoring criteria used for grading. Students were also shown the final products of students who completed the course in past years, although they were not allowed to retain these.

Students were required to include three concepts, 1) the pharmacist, 2) the patient, and 3) pharmaceutical care, and to make pharmacy communications the focus of their map. They were encouraged to incorporate material from other courses, but had to demonstrate the connection of the material to pharmacy communications. Students submitted first and second drafts during the semester, and a final draft was due on the last day of class. Each draft was graded, but the grade value of the first and second drafts was kept low so that the experience involved minimal risk as students developed greater skill in working with the concept mapping technique. Given that students had to work on the assignment throughout the semester, the final draft of the concept map was weighted so that together the three drafts of the assignment represented 25 percent of the final grade. The students are also graded on their participation in small group conference activities, and complete two midterms and a final exam. Students received feedback on their work so that they could make improvements and correct their understanding of the course material and assignment prior to submitting the next draft. The quality of most of the groups' concept maps was excellent, and it was immediately obvious which groups had invested significant time, effort, and creativity in completing their finished maps. See Figure 1 for a sample of one group's concept map.

Roth and Roychoudhury (1993) suggest that concept mapping can serve to facilitate collaborative and cooperative learning. In this course, students worked in self-selected groups of three to five to create a mutually acceptable concept map and a narrative that explained the decisions made in its organization. The map individual students created of their existing knowledge of the role that communications skills play in pharmacy practice provided them with the material with which to begin their group conversations and helped students document their existing knowledge for the narrative. In order to create a mutually acceptable group product, students needed to cooperate and negotiate meaning within their group discussions. The need to negotiate meaning in a group setting also helps students prepare to work as a member of a healthcare team.

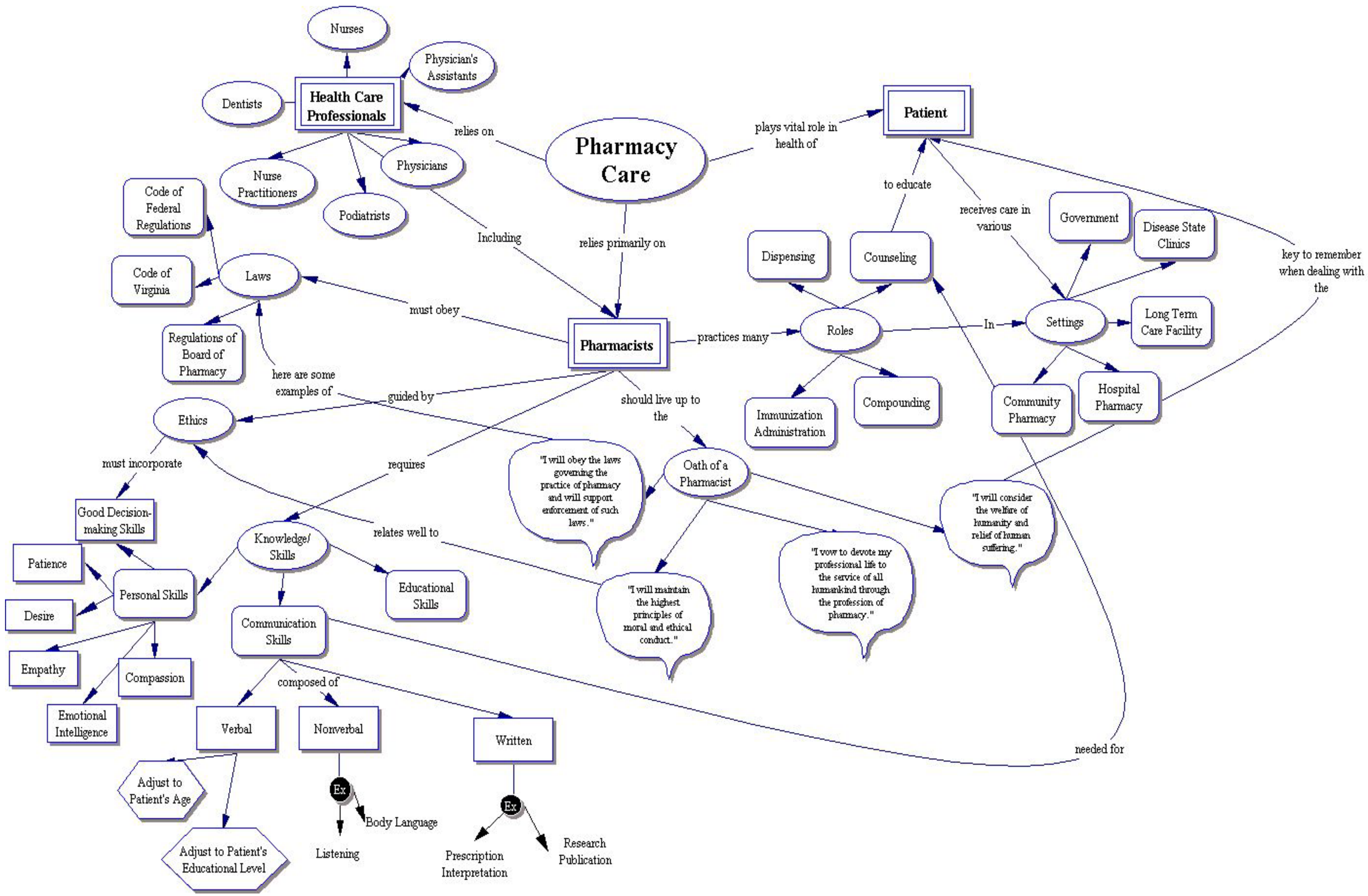

Figure 1: Sample of Student Concept Map

3 Assessment of Student Learning

The emphasis in grading both the concept maps and the narrative should be on the meaning group members have made from the subject material in the course and its interrelationships and avoid simple counting of the number of elements included. Once students suspect that numerical scoring prevails, they are tempted to crowd their maps with as many concepts and linking words as possible, and to create multiple cross-links whether they have validity or not. An evaluation rubric developed by Trepagnier (2002) examines the original thinking used in developing links between concepts and their accuracy, the theoretical accuracy demonstrated by directional arrows within the maps, and the accuracy and creativity displayed in writing the narrative. Maps that are rated as excellent have accurate and insightful links on the concept maps and indicate independent thinking. By contrast, maps that need improvement or are unsatisfactory include inaccurate links and misconceptions in both the map and narrative.

3.1 Students' Perceptions of the Assignment

Information regarding students' perceptions of the class and the assignment was collected during the semester. Approximately 6 weeks into the course, students were asked to fill out an informal formative evaluation form containing several sentence stems they were to complete. Student comments and their frequency are reported in Table 1. Students could make comments in each category. It should be noted that in every category except "The concept map . . ." students were commenting on the course as a whole, and not just the concept mapping assignment. This explains why there are only a few comments about the concept map assignment in some categories.

Students reported that while valuable, the process of concept mapping was challenging. They had to learn how to organize a concept map and link concepts together. Other comments related to uncertainty with the process and the feeling that it felt more like brainstorming than an orderly progression. Some students appeared to have enjoyed the assignment and they commented that they found it useful in organizing their ideas, retaining information, and relating the communications course material to other courses in the curriculum. One student liked the process so well that she used it to study for a difficult exam. Several students responded that the concept maps were challenging and provided them with some difficulty, yet at the same time some also responded that they found it a useful exercise that helped them better understand the role of communications and the pharmacist in providing pharmacy care. In several instances, a single individual commented that the exercise was both challenging and that it was helpful in learning. A few students commented that they appreciated gaining experience with a new learning tool that they could use to study for other courses.

Just past the midpoint of the course, a second exercise solicited responses to specific questions about student experiences of the concept mapping process. Both positive and negative comments were received. Students responded that "*Creating a concept map helped me organize my notes for studying*," "*Is a good way to show and learn how different aspects of pharmacy are interrelated*," "*Taught me a great deal about the pharmacy profession*," "*Is helpful in connecting ideas related to pharmacy and remembering them*," *"Is a fun project*," but at the same time several students remarked that the assignment "*Was challenging*."

Comments from both exercises are similar to those reported by Trepagnier who used concept mapping to teach sociology.[2] She also reports receiving a mixture of positive and negative comments. Student responses indicated that both *dis-equilibrium* and *equilibrium* occurred during the concept mapping process. Dis-equilibrium signifies that students experience uncertainty and search for information to clarify their understanding while equilibrium refers to regaining comfort with material by achieving understanding and the restructuring of mental schema held about the subject. Trepagnier indicates that most students felt that the exercise helped them learn the concepts taught in the course. She concludes that concept mapping requires students to engage in constructivist learning processes to comprehend whole-part relationships in order to create a comprehensive, interrelated picture of the material taught in a course.

Novak concludes that the sophisticated concept maps produced by university students represent, "an enormous amount of knowledge. . . . The construction of the map requires considerable creativity in organizing the structure of the map, selecting important, relevant concepts to add to the map and searching out salient cross-links, indicating relationships between concepts in different sections of the map. Needless to say, the map becomes an important learning experience for my students as well as a unique evaluation experience" [1] (p. 192). Novak notes that scoring criteria must also be specific and clearly related to the objectives of the assignment.

The Concept Map . . .	
▪ Was a helpful tool in exploring communications and pharmaceutical care and in understanding the role of the pharmacist in patient care.	8
▪ Is challenging.	8
▪ Is a good experience. I enjoy coming up with new concepts and figuring how it relates to others.	7
▪ Is a new assignment for me. It really makes you sit down and put everything together.	6
▪ It organized my ideas from reading and lectures.	5
▪ Helped me learn and remember better the concepts presented in class.	5
▪ Is a fun way to link our ideas and show what we know and what we learned.	4
▪ Helps to clarify knowledge about the practice and the profession of pharmacy.	4
▪ Is a good and applicable concept that can be applied to other classes used as a study aid.	4
▪ Was a good, innovative way to learn about communications.	3
▪ Does not help me understand the relationships we discuss.	3
▪ Finding time to work on it is the hardest part.	2
▪ Was somewhat difficult for me to understand and create.	2
▪ Helped me to see the broad idea. Is a good way to organize ideas.	2
▪ Takes a lot of time and coordination.	2
▪ Is helpful in connecting ideas that we related to pharmacy and remembering them.	2
▪ Is a great opportunity to work in groups and learn pharmacy practices from my peers.	2
▪ Helps to put info from different classes together.	2
▪ Seemed like an easy idea at first, but was harder when it actually came time to do it.	2
▪ Is confusing, but it helps to learn more about the different aspects of health care.	2
▪ Was a valuable learning tool and more difficult than I had anticipated.	1
▪ Importance/value remains to be seen.	1
▪ Proved to be an interesting way to explain something and to teach and learn other concepts.	1
▪ Was my favorite section of the course!	1

I learned the most when . . .		I was surprised by . . .	
▪ I was researching the concept map.	1	▪ How helpful concept mapping is as a learning tool.	1
▪ Using the concept mapping.	1		
▪ We connected all the lines in the concept map and made the final product.	1	▪ How easy it was to use the concept mapping software.	1
▪ Putting all the thoughts together in the narrative for concept map.	1	▪ My ability to come up with concepts for the map.	1
		▪ How easy it is to become carried away with the concept map	1

I will remember this material because . . .		Things became clear to me because . . .	
▪ I used the concept map to give the information structure and how it fits into the scheme of things.	1	▪ I looked to my concept map for organization	2 1
		▪ I used a concept map as a tool to learn important information.	1 1
▪ The concept map has helped me to relate to the concepts better in class and conference has helped to reinforce it.	1	▪ By using concept map skills, I could organize things better.	1
▪ I related it to concept mapping and was able to organize the material.	1	▪ I studied from the concept map.	

I had the most difficulty with . . .	
▪ The concept map	1
▪ Knowing how to organize the concept map with linking words.	0
▪ Getting started on the concept map, but once we organized our ideas it became easier.	8
▪ Finding linking words for the concept map.	6
▪ Writing the narrative for the concept map.	3
▪ Formulating ideas for the concept map.	2
▪ Simplifying and linking concepts together in map. It felt more like brainstorming	1
▪ Breaking down the concept map topics.	1
▪ I am not a visual or artistically-oriented person, so this is very difficult.	1

Table 1: Frequency of Student Responses to Formative Evaluation Questions

4 Sources of Support

I first learned about concept mapping for visual learning through a colleague at another university. I had expressed my frustration to her after the first year of teaching the pharmacy communications course that students seemed to believe the material taught in this course is less important and relevant than concurrently scheduled basic science courses such as anatomy and physiology. I was concerned that the students relied heavily on rote memorization as their primary learning and study method. My colleague has used concept mapping in both her teaching and research, and had the privilege of studying with J. D. Novak of Cornell University. She suggested that I use concept mapping in my course, shared resources with me, and we have continued to dialogue about the concept mapping process and share ideas and teaching strategies.

I found other faculty colleagues at my university who use concept mapping to teach in other disciplines. We shared ideas and resources. Eventually two of us were invited to make a presentation regarding concept mapping for the university's Center for Teaching Excellence. Through presenting my concept mapping work at the national pharmacy education conference, I have found other faculty in pharmacy education using the process in their teaching and curricular planning. We have discussed the issues in concept mapping and learned from each other.

5 Resistance to the Assignment

Resistance to the concept mapping assignment came from several sources and seemed to center around three issues: the assignment's unfamiliarity and related doubts about its value, the required time investment, and resistance to change. I had not anticipated that it would be necessary to promote the assignment to administration and my peers.

5.1 Student Resistance

For most students, learning to create a concept map is an unfamiliar process. Some students will have experience with mind mapping and other brainstorming techniques and must be taught to differentiate what is unique to a concept map, namely the creation of linking words to indicate relationships between concepts, development of a clear hierarchy to differentiate general concepts from specific ones, and the use of cross-links to demonstrate logical connections between different sections of the map. Expectations for students must be clear and specific and a credible rationale for why they are required to undertake this assignment must be provided.

Some students indicated that they did not believe they were visual learners and that the assignment did not suit their learning style. Other students felt that they did not find the concept mapping process natural or comfortable, and one person indicated that he would be glad to never do this again. In a class of more than 100 students, different learning styles will always be present and a variety of techniques are used within the course to accommodate students' learning needs. The educational literature related to learning styles indicates that while many styles can be accommodated within a course, people must also *learn to learn* in different ways regardless of whether they are immediately comfortable. Some students may be uncomfortable with the concept map assignment because of its unfamiliarity and the experience of mental dis-equilibrium this assignment and all learning have the potential to create. Novak (1998) comments that while students may recognize the value of concept maps as learning and evaluation tools, they also recognize that creating a worthwhile map takes significant time and effort. After years of schooling that emphasizes rote memorization of information, instructors should not be surprised that students find being asked to take responsibility for constructing their own meanings to be challenging (Novak, 1998; Sternberg, 1998).

Another source of student resistance was the requirement to work in small groups. This is commonly encountered by faculty who assign group work, and appears to be based on the time commitment required to meet with other students outside of class. It may also indicate students' lack of trust in their classmates. For the second year of this assignment, peer- and self-assessments were designed. The self-assessment turned out to be the most useful because it required students to document the time spent working individually and group meetings. Large time discrepancies within a small group were used as a potential indicator of the need for instructor intervention. The group assignment format was practical for the instructor in a large class, and by the end of the semester several students indicated that they realized that the assignment was a good experience in preparing to become a member of a healthcare team.

5.2 Faculty Resistance

Other faculty were dubious about the value of concept mapping, but their resistance was mainly concerned with the time this homework assignment required of students. The school's Curriculum Committee advises that for each class hour, students should invest three hours in homework. In fact, this assignment did not exceed that mandate, and in many cases students invested less time. There was sufficient time left over for other course homework, and the assignment did not impinge on the time required for other courses scheduled in the same semester.

5.3 Administrative Resistance

Initially, the school's executive associate dean was excited by the students' concept maps and was very supportive of the assignment. The school's technology committee approved a request to install Inspiration software in the workstations of the student computer lab. The software request stated that, "my intention in creating the concept map assignment was to alleviate my concern that students were leaving the course with disparate ideas that were disconnected from pharmacy practice and other courses in the curriculum." Inspiring students to achieve long-term integration of knowledge is essential in a knowledge-driven profession, and pharmacy accreditation standards state that "the organized program of study should provide students with a core of knowledge, skills, abilities, attitudes, and values necessary to the provision of pharmaceutical care."

I had not anticipated that there would be administrative opposition to using concept mapping in this class, but should have realized that some assertive students will direct their complaints directly to the associate dean of students, and if they aren't satisfied with the response address their complaints to the dean. Rather than be supportive of innovative teaching, the resistance culminated in a directive to discontinue use the assignment just as the Inspiration software was being installed. In explanation, I was told the assignment was "too difficult for first-year students." This is rather puzzling considering that concept mapping has been used with elementary children.

6 Discussion and Conclusions

Incorporating a concept map assignment into an existing course requires the instructor to invest significant thought, time, and effort. It is necessary to review the course learning objectives and think about how the assignment will help students achieve them. Instructors need to develop clear expectations for students and explanations for the assignment as well as a credible rationale for why they will be required to engage in this unfamiliar process. Grading concept maps also requires a large time investment particularly when several grading points are spaced across the semester. The reward for the instructor are that concept mapping can help students to understand abstract material within a course, integrate learning from related courses, and engage students in grappling with conceptual material so that they are challenged to move beyond rote memorization to meaningful learning. Instructors can dialogue with students about course topics in a novel way and gain appreciation for the depth of student learning. Students can benefit by gaining experience with a new learning tool and in the way this assignment is structured, students also gain experience with teamwork and collaborate as they work to create a mutually acceptable final product within an imposed deadline.

Despite all these positive benefits, a faculty member's good intentions and investment of time and effort can be misconstrued and devalued. No other part of the faculty role consumes so much intellectual energy as teaching, and yet faculty creativity is infrequently documented and shared (Bernstein, 2002). Faculty members usually have a great deal of latitude in selecting teaching methods and assignments. However, this was not the case in this instance, academic freedom notwithstanding. It was clear that I might have been more successful if I had invested more effort in promoting visual learning to my peers and administrators.

7 Acknowledgements.

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THE HIGH COST OF KNOWLEDGE RECOVERY

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Abstract. Knowledge recovery is the process of culling meaningful propositions from documents and crafting them in the form of Novakian Concept Maps, thereby making the material more useful and usable. This report discusses our first major effort at knowledge recovery. Expert knowledge about terrain exists in the form of traditional documents discussing landforms, soils, rock types, etc. (Hoffman, 1983; Mintzer & Messmore, 1984). These were recast as Concept Maps in ROCK-TA ("Representation Of Conceptual Knowledge-Terrain Analysis"), which is a very large knowledge model, consisting of over 150 Concept Maps, containing over 3,000 propositions, and dozens of multimedia resources (text pieces, aerial photos, maps, etc.). The knowledge recovery effort was very costly in terms of time and effort, suggesting that knowledge-based organizations should attempt to make knowledge capture an on-going aspect of work, rather than finding themselves in the situation of needing to recapture knowledge. A second aspect of the work reported here involved the need to support navigation among the many Concept Maps in ROCK-TA.

1 Introduction

Terrain analysis is a formal systematic process in which aerial photographs, topographic maps, and other data sources are used to understand terrain and then apply that understanding, especially for engineering and land use (e.g., engineering properties of soils and rocks, waterways management, land-use planning, etc.). Expertise at terrain analysis is achieved only after years, if not decades of experience at interpreting aerial photographs (Hoffman, 1985; Hoffman & Pike, 1995). Therefore, the capture of terrain analysis expertise is of great potential value, for knowledge sharing (e.g., training) as well as knowledge preservation.

Expert-level knowledge about terrain and terrain analysis exists in the form of traditional hardcopy documents. As such, the information is hard to access and is of limited usefulness and usability. It therefore seemed an appropriate topic for a study in the process of knowledge recovery, in which the information is recast in the form of Concept Maps.

2 Method: Creating the Knowledge Model

2.1 Materials

The Terrain Analysis Data Base (TADB) (Hoffman, 1983) is a corpus of about 1500 property and association statements about terrain. These were derived by documentation analysis and structured interviews with expert terrain analysts at the US Army Corps of Engineers Engineering Topographic Laboratory. The TADB involved representing domain concepts and propositions as hierarchical lists, for two reasons: 1). The domain itself is largely one involving hierarchical classification, and 2). The TADB entries were ordered because they were intended to be an intermediate representation for possible applications in knowledge bases for rule-based expert systems. Thus, the TADB entries were of a form readily transformable into Concept Maps. An example of a TADB entry is:

- Landforms
    - Fluvial Landforms
        - Alluvial Fans
            - Fan-shaped deposits
            - Gentle slope
            - Rugged upstream boundaries
            - Box-, v-gullies with steep gradients
            - Usually in arid regions

2.2 Procedure

The first step was to transform the TADB entries into propositions. In most cases, this involved the need to modify the wording of the TADB statements, most of which had an implicit propositional structure. Thus, for example, the Concept Map about Alluvial Fans included the following propositions:

Alluvial fans have morphology
Morphology includes fan-shaped deposits
Morphology includes gentle slope
Morphology includes rugged upstream boundaries
Alluvial fans have drainage pattern
Drainage pattern is box- and V-shaped gullies
Gullies have steep gradients

As another example, some high-level information about Deserts was represented in the TADB as:

- Deserts
    - Sand and gravel soils
    - Usually arid climate
    - Desert varnish tones
    - Occasional silt soils
    - Usually with dunes

This same information was represented as propositions and then represented as a Concept Map that appears in Figure 1, below. Note that this preserves the semi-heirarchical structuring of the TADB: Higher order concepts are nearer the top of the map, and lower order concepts are nearer the bottom of the map.

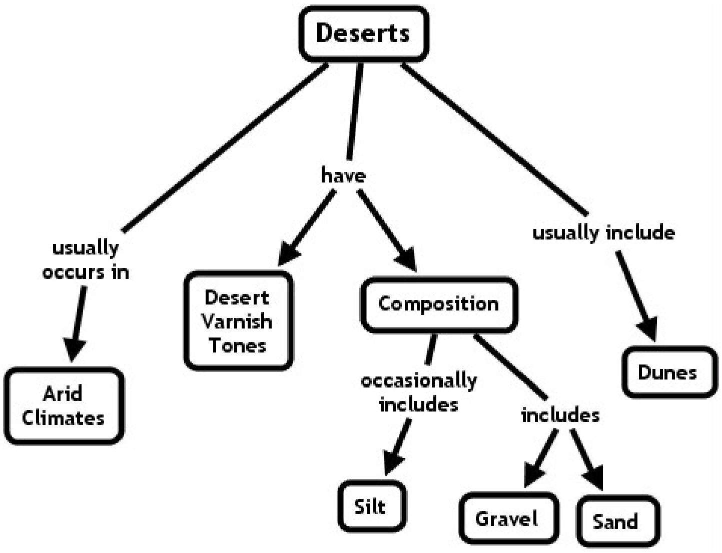

Figure 1. An example Concept Map representing propositions from the TADB.

Once the draft Concept Maps had been created, a series of structured interviews was held. The first and fourth authors of the present Report served as facilitators. The first author served as the local expert and also served as the Mapper. Working together, they reviewed the TADB and compared it to the draft Concept Maps. Refinements were made to the Concept Maps. A triple-check was conducted to insure that all of the statements in the TADB were included as propositions in the Concept Maps.

Another important resource for our work was the "Terrain Analysis Procedural Guide FOR Surface Configuration" (Mintzer & Messmore, 1984). This includes a great many photo interpretation keys for landforms of all types, including topographic maps and aerial photographs. These interpretation keys and aerial photos were used as multimedia resources for the final Concept Maps.

3 Results

The knowledge model consisted of 150 Concept Maps, containing a total of 3,341 concepts, 1,634 link labels, and 3,352 propositions. The Concept Maps contained an average of about 22 propositions. It took a total of between 187.5 person-hours and 225 person-hours to draft all of the 150 Concept Maps. This equates to an average of 75-90 person minutes to create each of the draft Concept Maps. (Detailed notes of time and effort were not made during the initial drafting of the first dozen Concept Maps. The lower and upper bounds we present here were based on estimates for that first wave of map drafting, but detailed notes of time/effort that were taken in all of the subsequent work.) It took 33 person-hours to refine the draft Concept Maps. This means that the process of recovering the TADB information in the form of propositions in Concept Maps took a total of between 220.5 and 258 person-hours.

Given that the final set of Concept Maps contained 3,352 propositions, the ROCK-TA Concept Maps were drafted and refined at a rate of between 0.25 and 0.22 propositions per task minute. This result falls considerably short of the benchmark for effective knowledge elicitation (Hoffman, Shadbolt, Burton, & Klein, 1995). The yield of 0.2 propositions per task minute is roughly equivalent to that for knowledge elicitation via protocol analysis, which is believed to be the *least* efficient method for eliciting expert knowledge (see Hoffman et al., 1995). For comparison purposes, Concept Mapping knowledge elicitation (without any knowledge recovery step) has a yield of about 2 propositions per task minute (seer Hoffman et al., 2000).

4 Implication of the Results

The meaning of this effort calculation—a yield of about 0.2 propositions per task minute—should be considered in light of the fact that the participating local expert who had helped create the TADB happened to also be a proficient Concept-Mapper. No doubt, the refining of the Concept Maps would have taken even longer had this not been the case, and the yield of propositions even less than 0.2 per minute. Furthermore, our effort leveraged the fact that the TABD entries were already of a form readily transformable into Concept Maps. Were this not the case, that is, if the TADB had been in the form of traditional text, then the knowledge recovery process would have taken much longer, arguably perhaps as much as an order of magnitude longer.

In light of these considerations, the moral of our results is clear for any organization that in confronting issues involving the loss of expertise (see Hoffman & Hanes, 2003): *Knowledge recovery is costly.* Any knowledge-based organization is better off capturing knowledge in a usable and useful form as a part of the organization's on-going knowledge management program, rather than finding itself in a position of losing expertise because of retirement, or the "wasting" of knowledge because it is archived in older forms of media (i.e., hardcopy text) that are not easily compatible with newer hypermedia forms and formats.

Having created ROCK-TA, we realized that the 150 Concept Maps would benefit from having multiple support tools for navigation. This was a focus of a second effort.

5 Creating the Navigator

Concept Map knowledge models depend on a method to support navigation. This has involved appending CmapTools icons to concept nodes (e.g., Hoffman, et al., 2000). Given the size of ROCK-TA, it was decided that it would be prudent to exercise a known principle of cognitive science: In information search and perception, redundancy is helpful. This idea was manifested in our adoption of redundant methods for navigating among the ROCK Concept Maps, and leveraged the fact that the ROCK-TA Concept Maps were arranged hierarchically in accordance with the hierarchical arrangement of the TADB.

The ROCK-TA Navigator included a number of mechanisms, described in Table 1.

The top concept node in each Concept Map, which bears the title of the Concept Map (i.e., its main topic), had appended to it a Cmap resource icon that would take the viewer up one level in the hierarchy.
A high-level Concept Map was created, called "The Representation of Conceptual Knowledge in Terrain Analysis." This Concept Map provides some important high-level explanatory concepts ("landforms," "climate," "soils," etc.) that form a general description of the major areas of knowledge in terrain analysis. This Concept Map serves as the user's gateway into the knowledge model. From it, the user can go to the Navigator or to the Top Maps.
A "Map of Maps" was created. A Maps of Map has nodes for all of the Concept Maps, and shows how each Concept Map is related to the others in the overall hierarchical scheme.
"Top Maps" were created to cluster Concept Maps into meaningful groups. Thus, for example, all of the Concept Maps about various types of sand dunes were linked together in a Top Map about Dunes. Like all Concept Maps, Top Maps display higher-order concepts (in this case, nodes depicting other concept Maps) nearer the top, and lower-order concepts nearer the bottom. The user can open a Top Map and use to see the overall relations between higher order concepts and use it to navigate between the subsumed Concept Maps, because double clicking a node opens the relevant Concept Map. Third, where appropriate, Top Maps were themselves organized under Subsuming Top Maps. For instance, the Dunes Top Map was subsumed under the Aeolian Landforms Top Map, which was itself subsumed under the Landforms Top Map.
"Maps of Top Maps" were made to show how all of the Top Maps relate to one another.
The top concept node in each Concept Map was hyperlinked to the "The Representation of Conceptual Knowledge in Terrain Analysis" Concept Map.
A "ROCK-TA" concept node was added in the upper left corner of each Concept Map. From this node, one would be able to navigate to the Map of Top Maps or the Map of Maps.
A Navigator "Cmap Piece" was added at the left-hand side of every Concept Map. This Cmap Piece showed how the given Concept Map fit into its subordinating hierarchy of Top Maps. Using the Navigator Cmap Piece, users can navigate up to superordinate Top Maps.
Once all the Navigator Cmaps and Top Maps had been created, all of the Concept Maps were hyperlinked. For example, the map "Terminal Moraine" describes key concepts associated with the moraine deposited by glaciers, one of which is the concept of "depressions." A separate Concept Map, called "Depressions" describes depressions in greater detail.

Table 1. Mechanisms of the ROCK-TA Navigator

The goals for including these multiple redundant navigational tools were: a). To allow the user to get from anywhere in the knowledge model to anywhere else, in two clicks at most, and b). To allow the user to always be able to see, know, and keep track of where s/he is in the knowledge model. Figure 2 presents an example of a subsuming Top Map. In ROCK-TA, all Top Maps have a colored background. The Top Map in Figure 2 example points to a number of subsumed Top Maps (colorized). The uncolored nodes refer to Concept Maps.

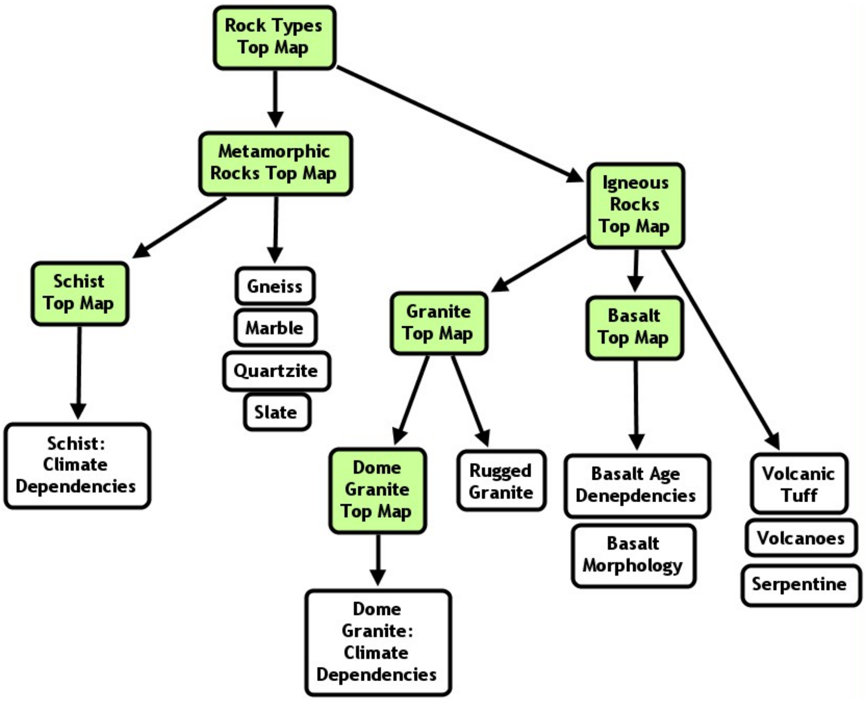

Figure 2. An Example Top Top Map in ROCK-TA.

Figure 3 presents an example of a Top Map that contains its Navigator Cmap Piece, on the left-hand side of the view. In such a Cmap Piece, the lowest node represents the Top Map that is immediately up in the hierarchy, and each node above that represents the next levels up in the hierarchy. The subordinating relationships of the nodes in the Navigator are indicated by arrows. Clicking on any of Cmap resource icons appended to the nodes in the Navigator opens the relevant Top Map. In Figure 3, the concept "Deserts" is subsumed by the higher order concept "Aeolian Landforms."

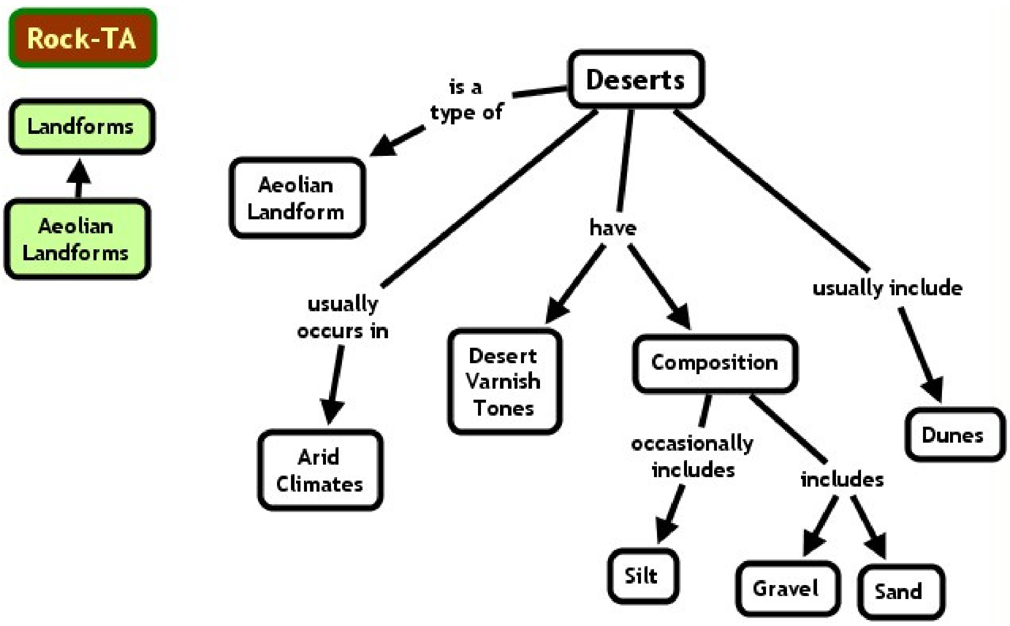

Figure 3. An example of a Concept Map that includes its Navigator.

A rule of thumb in Human-Centered Computing (HCC) is that if a display or interface system requires navigation, and especially if the navigation system has to be explained, then the system will create make-work for the user, no matter how "user friendly" it is intended to be. It is important to keep in mind, however, that HCC regards the human-machine as a *system*. ROCK-TA is intended for use by individuals who are already accustomed to working with CmapTools knowledge models. In other words, the intended users belong to a new culture for knowledge sharing. Thus, for the human-machine system that we envision, explanation of the Navigator should not be an issue: It should explain itself.

6 General Discussion

It took over 366 person-hours to create ROCK-TA. (This includes the time taken to append dozens of various multimedia resources, such as example aerial photographs.) As we have explained, the knowledge recovery step was time-consuming and relatively inefficient compared to other knowledge elicitation procedures (see Hoffman, et al., 1995). On the other hand, the result is a knowledge model that includes all of the propositions from the Terrain Analysis Date Base. This single compilation, transferable to CD, contains the collective experience, skill, and guidance from of some of the world's leading terrain analysts, most of whom retired not long after they created the documents and other sources upon which we relied.

In its current form, ROCK-TA might be most useful as a teaching tool or learning aid in courses on terrain analysis. It might also be a useful resource for professionals to have on hand. ROCK-TA contains generic information about terrain. "Daughters of ROCK" might be specifically tailored for local needs, such as the representation of information about terrain in particular regions. We see such daughters of ROCK-TA as relying on ROCK-TA for their backbone of domain knowledge, but going into more detail for more specific regions and purposes.

7 Summary

A neglected aspect of knowledge management and the preservation of expertise is "knowledge recovery." Expert-level knowledge in many domains has already been elicited and preserved, but exists in the form of traditional text documents. This makes the material difficult to access and difficult to understand and use. Knowledge recovery is the process of culling meaningful propositions from documents and crafting them in the form of Novakian Concept Maps, thereby making the material more useful and usable. This report discusses our first major effort at knowledge recovery. Expert knowledge about terrain exists in the form of traditional documents discussing landforms, soils, rock types, etc. (Hoffman, 1983; Mintzer & Messmore, 1984). Previous IHMC research (e.g., Hoffman, Coffey, & Ford, 2000) had demonstrated that Concept Mapping could be used as a knowledge elicitation procedure and could result in a model of expert domain knowledge that captures relations among myriad elements of knowledge (Novak, 1998). Details of the process of creating ROCK-TA ("Representation Of Conceptual Knowledge-Terrain Analysis") are provided in the present Report. ROCK-TA is a very large knowledge model, consisting of over 150 Concept Maps, containing over 3,000 propositions, and dozens of multimedia resources (text pieces, aerial photos, maps, etc.). ROCK-TA is intended as both an instructional tool and a performance support tool for practitioners who have to engage in terrain analysis. A major finding from this effort concerns the process of knowledge recovery. Our participant expert at terrain analysis was involved in the creation of the original source documents on terrain analysis, and also was a proficient Concept Mapper and participated in the creation of the Concept Maps. This should have made the knowledge recovery process as efficient as possible. In fact, the effort was very costly in terms of time and effort. This result clearly suggests that knowledge-based organizations should attempt to make knowledge capture an on-going aspect of work, rather than finding themselves in the situation of needing to recapture knowledge. A second aspect of the work reported here involved the need to support navigation among the many Concept Maps in ROCK-TA. Our approach involved the notion of a "Cmap Piece." A Cmap Piece is a small Concept Map that appears within the window of each main Concept Map and allows the viewer to always be aware of where they are in the knowledge model. A demonstration of ROCK-TA will show how the Navigator works.

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APPLYING CONCEPT MAPS AND HYPERMEDIA TO FILM ANALYSIS

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Abstract. This article describes an open concept map-based hypermedia system for film analysis and film teaching (direction, narration…). It uses concept maps as navigational and conceptual structure for non-linear access and flexible interaction on multimedia materials for film analysis or study. Cmaps and Hypermedia fit very well the objectives of this project they allow for the exploration of new ways of analyzing films, as well as an active film watching and new ways of film appreciation, which might be seen as the equivalent for films of an individual, customized class in a museum to appreciate masterworks paintings from the past. The methodological model and the demonstration and evaluation prototype being built are described in the paper. The impressive set of semiprofessional facilities commonly available today (concept map software, films in DVD, hypermedia tools, free or affordable DVD software on PC, etc.) makes it possible a new way of appreciating the film masterpieces as they drew and defined the language of motion pictures near perfection.

1 Introduction

Concept maps have not been used, to our understanding, as a tool for audiovisual products analysis. We see concept maps very well suited to provide both structured and flexible access to hypermedia documents as well as to build interactive applications like the described in this article. Concept maps are recognized as very effective for knowledge organization and communication tools.

Our target was to build an open system based on CmapTools with full access capabilities for film analysis and criticism. It is a concept map based hypermedia system that allows the non linear access to contents and the interactive film analysis. We think such a tool is applicable by film critics, film teachers, film aficionados for sharing knowledge and cultural contributions in active ways. We think it might open a new way for film criticism and film discussion via Web.

It is surprising as well the fairly low usage of hypermedia facilities for film related activities such as criticism, analysis and teaching. The predominant approach seems to be the same as for literature or art: textual analysis with offline access to the criticized work. It is alarming the lack of connection (links) between film material and "hypertext" material. In other words, the analysis and teaching of films does not fully exploit the widely available capabilities of hypermedia. When looking to hypermedia applications to film teaching and analysis, our search did get few results: there are lots of hypermedia applications for teaching in general, but not for film analysis or teaching.

Hypermedia typical non linear access is well suited to the analysis of films. While current film criticism works separately from the criticized product, hypermedia allows the analysis to be read at the same time that the object of analysis. Our objective was to create with hypermedia something similar in part to the Spanish TV program "¡Qué grande es el cine!", that is like a cine forum session where different film experts first introduce a film and at the end comment it, their comments being illustrated sometimes with the cited sequences.

Many considerations support the adequacy of concept maps for films:

- Films are sequential systems when watched, and the spatial representation provided by the concepts maps can show clearly the film structure in detail. However some more specific time diagrams may help for an improved film analysis and description as concept maps are not specifically adapted to show detailed time relations in a condensed form.
- Structure signifies by itself. This is a well known advantage of concept maps.
- The message is multimedia itself. One of the great advantages of hypermedia for films is that the content to be “taught” is neither science or literature, but multimedia itself (film). The content is conveyed by itself, accompanied with all kind of helps for understanding.

This paper is organized as follows: in the introduction we have stated our objective and initial approach. In section two the previous work is briefly described regarding concept maps and hypermedia usage for film teaching or audiovisual document analysis. In section three the model for implementation is described. The prototype is explained in section four, including some conceptual maps examples and a brief discussion of the chosen tools to implement it. The paper finishes with a summary and consideration on future work on the evolution of the tool.

2 Related work

As usual when discussing hypermedia, precedent works normally are in multimedia form. Precedent projects as "Griffith in context", oriented to the ideological and formal analysis of Griffith's film *Birth of a nation* are based on a CD-ROM that contains the supporting material (clips extracted from the film selectable with a menu) and the film is visioned in the teaching room. This schema has an excellent teaching value but suffers from the disadvantages of the multimedia approaches: rigidity and a closed approach. The "multimedia lesson" is completely self-contained and not updated until a new CD-ROM edition is produced.

Abundant bibliography exists on hypermedia narration (Moreno, 2002) and application to teaching. The main rules of hypermedia narration are fully applicable to the project, although there is not "interactive narration" inside, at least not necessarily, although this interactiveness might be desirable for novice users (novice to film analysis and to the tool).

One of the closest approach is the DVD that David Monaco has produced as a hypermedia product, *How to read a film.* It condenses several books' contents, many video and audio clips and some interactive exercises. The pdf format is applied efficiently beyond limits of current usage, although the text content predominates. As it is well known, extensive textual content does not fit to be read on the screen. The product is commercialised as a DVD-ROM. The inhibition of the printing capability for protection purposes forces the reading of text on the screen, limiting its usability.

As an example of the change that hypermedia produces in film criticism, the web page *Kissology,* that compares kisses in six Alfred Hitchcock films, shows how the film criticism changes when the criticized film is available at the same time than the text and the film sequence can be replayed and analysed by the reader.

3 Deconstruction as a method of analysis

Although the tool may be used with any film theory for analysis, we focus specifically, although not exclusively, on deconstructionism because our tool could heavily help to the advance in new types of film criticism inspired in deconstruction. The term *deconstruction,* was coined by Jacques Derrida in the late sixties. Deconstructionism was a reaction to the excessive imperative of the *logos* in structuralism and lacanian psychology theories for interpretation. The American Heritage Dictionary defines deconstruction as "A philosophical movement and theory of literary criticism that questions traditional assumptions about certainty, identity, and truth; asserts that words can only refer to other words; and attempts to demonstrate how statements about any text subvert their own meanings: *"In deconstruction, the critic claims there is no meaning to be found in the actual text, but only in the various, often mutually irreconcilable, 'virtual texts' constructed by readers in their search for meaning*". Barbara Johnson clarifies the term: *"Deconstruction is not synonymous with "destruction", however. It is in fact much closer to the original meaning of the word 'analysis' itself, which etymologically means "to undo" -- a virtual synonym for "to de-construct.".. If anything is destroyed in a deconstructive reading, it is not the text, but the claim to unequivocal domination of one mode of signifying over another. A deconstructive reading is a reading which analyses the specificity of a text's critical difference from itself."* Derrida made apparent the process of critical decomposition and reconstruction, as a new way to analyze culture products. Ferrán Adriá (El Bulli restaurant), uses the term deconstruction in the sense of *re-composition in a different way*, for example changing textures and keeping the flavours of the ingredients. The current term usage is fashionable and not concisely definable.

Our approach can similarly provide not only a tool for film analysis, but *different ways of appreciating films* versus the classic linear or sequential watching, provoking a similar effect in the watcher: getting a different and deeper comprehension a film.

The film is decomposed into its different elements (narration, metaphors, symbols, sequences, etc), using hypermedia for establishing links between different elements, allowing the learner to do the opposite operation: the "re-composition". This way back into the whole film takes effect in the mind of the learner: the learner reconstructs the film in a way he could not have thought of before. When applied to film teaching, this approach allows for a deeper analysis and understanding of film masterpieces. Some authors use the term deconstruction in the sense of exposing the internal structure of a communicative item or of a discourse. We must mention here the work of (Litwin, 2000), reflecting on how the effect of "recomposition" takes effect in the mind of the person learning using hypertext and hypermedia.

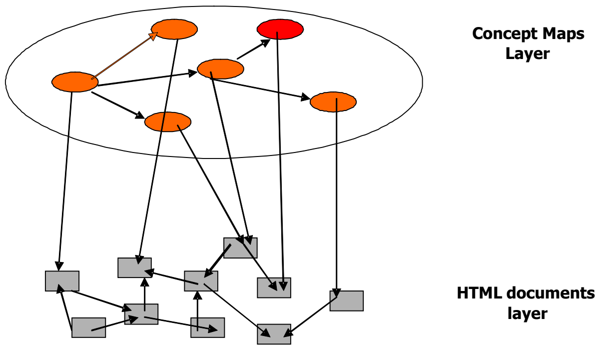

Fig.1 Film Tool two layered Model

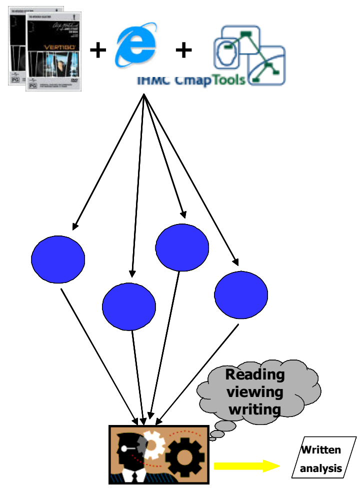

Fig.3 Deconstruction process with Film tool

4 Model`s description

4.1 Model Architecture

Our methodological framework for the film tool is based on J.J. García Rueda Doctorate Dissertation (García Rueda, 2002), where the two dimensions for the use of hypermedia systems in teaching environments are fully described: the Expositive Dimension and the Structural Dimension are analysed in depth. The Concept Maps are very well suited to express the Structural dimension. The Expositive Dimension is implemented through multimedia nodes. In our case, the system has a two layer architecture as shown in fig. 1. The upper layer is formed by concepts maps linked each other beginning with a concept map acting as a "home page" (see fig. 2) of the film tool. These concepts maps express in a general way the basic elements in films analysis. From these, it is possible to access information more specifically related to the film under analysis via hyperlinks. This specific information is implemented in nodes located in the lower layer, actually a hypermedia network layer. The node’s contents normally include text, video clips, screenshots, text templates and even interactive tests.

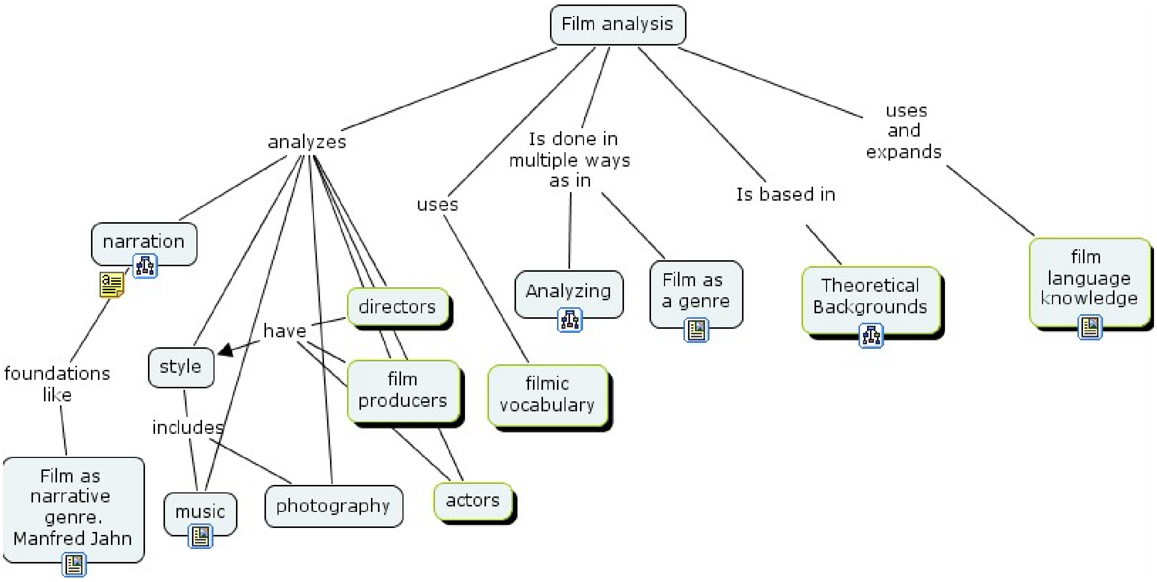

Fig. 2 Initial Cmap example

4.2 General Design Guidelines

4.2.1 Generalized indexes

Concept maps have been seen as generalized indexes. As the Contents section is the map of a book, a concept map serves very well as an enriched map to hypermedia content. We use this approach. Indexing information is getting increasing importance now that more and more informative resources are available via the Web and that every person's role as an information processor increases day after day.

Mapping is also essential due to the great improvement in speed and quality of communication that it provides.

4.2.2 Design of hypermedia

Hypermedia "narration" has its own rules as it is well-known in the literature, but not so much in cinema. It is essential to know the language of hypermedia (how to narrate with hypermedia), and not just the hypermedia software, although much more importance is usually given to the last.

In our project, "narration" is not exactly applicable in the same way as when telling a hypermedia story. However, basic language rules must be taken into account for an efficient usage of hypermedia. The tool must be simple, distractive events should be kept to a minimum, many complementary events shall be optional to the user willing to study some aspect in detail, without confusing the basic use and the navigational clarity of the tool. Regarding interactivity, the tool will have a higher interactivity than multimedia off line products as it uses on-line connections to Web pages and random access to the films contents. The T-MUM (Williams, 2003) taxonomy for hypermedia helps in classifying the hypermedia usage and function.

4.2.3 Openness and connectedness

Citing C. Tomás: "Network connectivity plus hypermedia makes possible new types of cultural products that are consumed in a non linear way, oriented to integration of knowledge, that departs from the centralized authorship, developing participative communication processes". The Web and information technologies change the way information is structured and obtained. It also makes it possible for the user to generate and connect cultural significances. In our project, we find that an example of this kind of product may be constructed around a concept map like "my view of the film Vertigo" which would correspond to a film critic view of the film enriched with the relevant material and extracts from many sources related to the author.

4.3 Design requirements

The design process of the tool prototype started with the capture of requirements. These included the types of users foreseen profiles definition, usability, flexibility and portability, conceptual design, detailed design with selection of tools, node identification, navigational structures, functions and contents. We also considered as a must the iterative evaluation of the prototype by professional film people and film students. From this experience, built on the prototype, recommendations for the final tool design will be derived. We also mention here the main requirements for the system to be designed:

- Compact. Minimum special HW requirements for maximum portability. Standard PC platform.
- Windows and Linux compatibility whenever possible.
- Free tools whenever possible for maximum diffusion, usage and collaboration.
- Flexibility and range of applications: to be used by a student as film analysis practice and by a film analyst cooperating with others, for simple analysis and for specialized ones, as a multimedia information organization and multimedia content access tool.

5 Prototype description

We discuss in this section the specificities of our prototype. In our approach to the prototype we considered that it should provide the user with conceptual and instrumental navigation aids for film analysis. The objectives of the prototype are: easy exploration of design, and evaluation and feedback from experts. Attractiveness and sophisticated effects are secondary in this prototype, although undoubtedly interesting for the final product, in order to promote its use among film students and film enthusiasts.

5.1 Tool selection

5.1.1 Concept Map tool selection

There exist different concept map platforms available. When selecting a mapping tool for our project we evaluated specifically Free Mind and CmapTools. Other mapping software products are MindMapper, Inspiration, Mindmanager and Kmap. Between the two basic approaches to mapping software, Mind Mapping and Conceptual Mapping, we had no initial bias for any of them. Practicing with both approaches in different applications we found that concept maps were fairly more suitable for our project than mind mapping due to its communicative precision which resides in the inherent statement structure of concept maps.

FreeMind is a Java based free mapping application that generates mind maps (crawl shape). It is fast when creating nodes and flexible in chaining maps and linking to documents in other formats. It also uses icons, colors and customization (clouds and the like) to attract the attention and differentiate among the essential characteristics of mind maps. It is a powerful and flexible information organizer, simple to use. As any mind mapping tool, it is less precise in knowledge organization and expression than concept maps.

We found CmapTools 3.3 very fast and flexible for constructing conceptual maps. A close relative of Cmaps are Topic Maps, that Cmaps currently offers compatibility with. For our application we needed flexibility of use and not precision in topic indexing, so Topic Maps were not considered, although connection to them in the relevant areas (film analysis, film language, etc.) might seem useful for specific information gathering. Cmaps are easily edited and exported to html format.

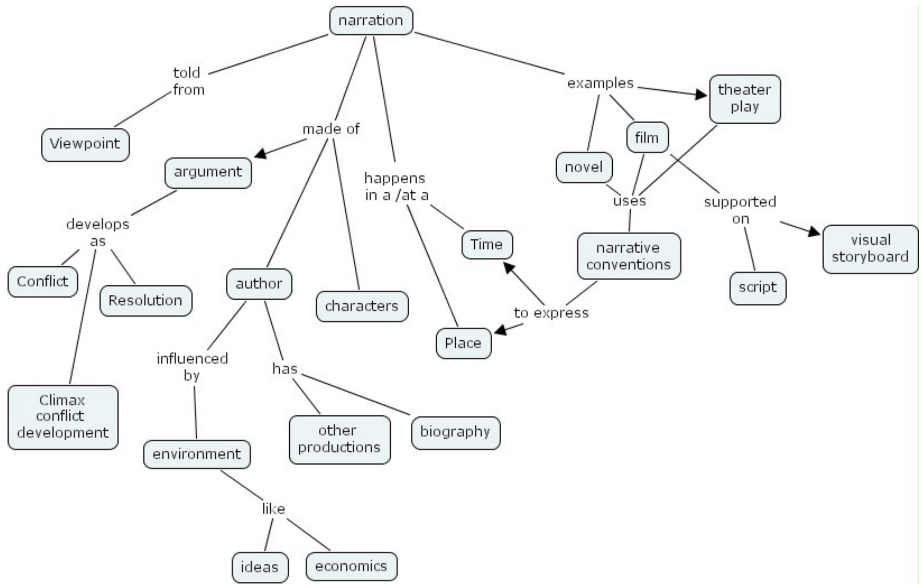

Fig. 4 . Example of Concept map for narration analysis

5.1.2 Playing clips

As said above, there are different alternatives for handling clips with film sequences for analysis. The DVD standard provides professional quality in home equipments.The most obvious consists of extracting clips off-line from the DVD and then linking them to hypermedia nodes for an easy playing from the tool. This has the drawback of the time required for clip extraction and the disk memory consumption, in this case compressed formats like DivX are recommended. We favour in general the use of software DVD players (such as VideoLan, Power DVD player) controlled by the user and by the tool. With software DVD players all the film is available, plus the extra material typically included in DVDs, that sometimes largely enriches the knowledge of the film making and participants. An intermediate option that software DVD player permits is to copy DVD files to disk and replay them from disk. In this way, scenes from different films may be available for replay and comparison. This is very interesting when analysing a director's style, for instance for a study of the use of travelling by Stanley Kubrick, travelling sequences from *Clockwork Orange*, *Barry Lyndon, The Shining* and *Paths of Glory*, may be played (even simultaneously) and compared. The same applies for the study of filmic genres styles evolution, as for example the treatment of revolver duels in western films by comparing duels scenes from classic and contemporary westerns.

5.2 Other supporting elements

For the prototype we have used theoretical background material from Manfred Jahn "Narratology" to study narration*,* David Monaco for film language theory and J. Cadavid among others for film analysis questionnaires and templates. However, the film analyst is free to use, include and link any relevant material suitable to the film in question or to the specific course's learning objectives, if the application is film teaching. So, under a similar or identical concept maps structure, different analysts can build totally different contents structures and "views" of the same film.

Terms and concepts used in film making are important for an efficient usage of our tool and for a good maps understanding. This is solved by providing links to Glossary and Thesaurus on films and on semiotics. Consistently with our approach, conceptual maps that show the main relationships between filmic concepts are also included. Access to multilingual film terms dictionary is also included for fast reference.

As part of the film product, the screenplay is considered a basic piece. Access to the screenplay on-line is currently feasible for many films. Links to it allow access for fast reference and or exercises. Access to storyboard is sometimes possible (i.e. parts of it are sometimes included in DVD), also, helping to understand the film creation process of the author. Access to the extra materials of a DVD in video format is possible by selecting the corresponding title in the DVD player. The technical data about the film (actors, producer, music and so on) is more accessible if captured via screenshots that appear as links inside the hypermedia nodes.

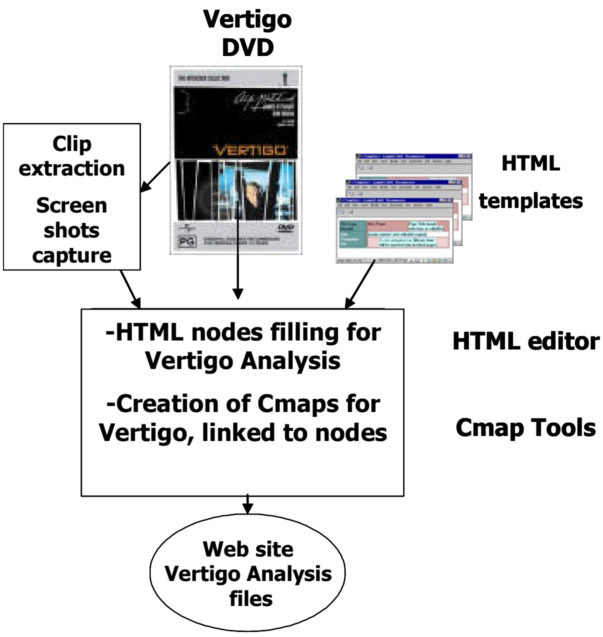

Fig. 5 Film tool usage (analyst)

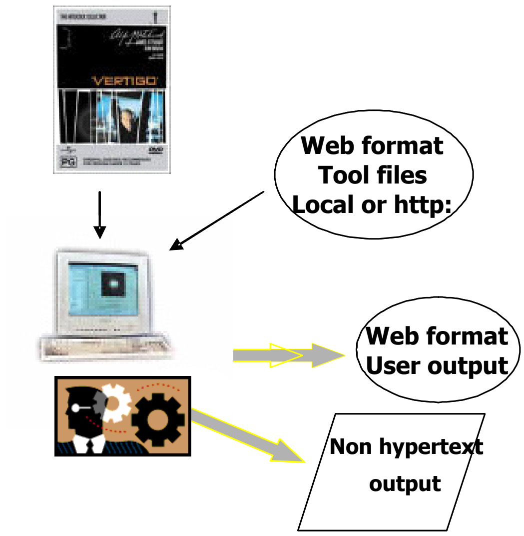

Fig. 6 Film tool usage (user)

5.3 *Prototype operation*

The usage of the tool prototype is shown in figures 5 and 6. Figure 5 shows the preparation of the analysis of film Vertigo that may include different types of annotations like video annotation. Figure 6 shows the "user" usage. We summarily comment on our experience with the prototype for Vertigo. Figure 7 shows an example for the initial page of Vertigo.

At the moment of writing, we do not have yet feedback from film experts on the prototype. Remote access to tool is under analysis to facilitate the prototype evaluation by film directors and film schools professors.

Regarding concept map production with CmapTools, the creation of the concept map file is simple and straightforward, and the export as .html file is straightforward. However if the page needs modifications in html links, no direct html editing is possible, the modification must be done in Cmap tools and the file exported again. The reason is that the html code generated by CmapTools is not human understandable (at least non-expert) for direct html editing. The integrated maintenance inside a tool like Dreamweaver is then not possible.

Regarding stored clips, compromises and alternatives are the norm. Depending on the requirements for portability (storage size for clips) we must balance image size and quality vs file sizes. The minimum for video are .mpg files with small size images (aprox. 2 Mb for a 40 seconds sequence). Good image quality with .avi may require about 50 Mb for the same duration. Most flexibility is provided by DVD playing selecting clip from a previously prepared playlist, accessing it by chapter, by timestamp selection with the time cursor in the Windows vlc interface or using the seek command of command line interface (on an MS DOS screen or preselected inside the tool).

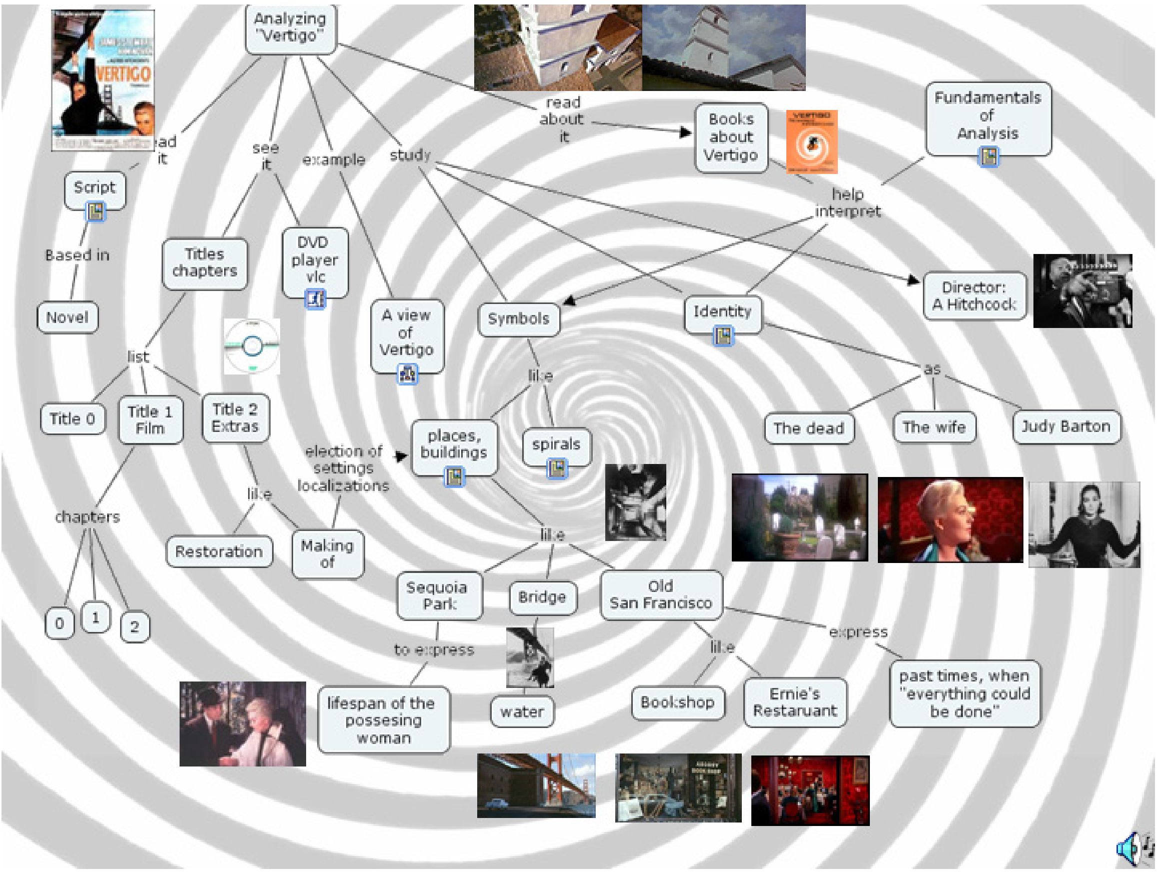

Fig. 7. Example of initial page for "Vertigo"

6 Future work

The described hypermedia system using concept maps seems useful in several areas related to films: film teaching, film analysis and criticism of a new type ("embedded criticism"), note taking on films, and perhaps as a communication vehicle between film enthusiasts. As a film teaching aid it helps a teacher to construct a consistent yet open environment for active learning. As an authoring tool, different, personal views of the same film may be constructed by anyone, as there are currently many books about a film.

Movie appreciation is enhanced as the movie can be watched actively and selectively. The magic of master film sequences emanates from them. Software DVD players use makes possible an integrated tool without bandwidth limitations and law infringements on authors rights.

Among the enhancements to the tool it might be obviously the access to movie sequence databases of indexed film sequences that would be accessed online via hyperlinks to illustrate examples of film styles, alternative solutions to same narrative sequences and the like. This looks difficult due to author's right restrictions and lies more in the cinematographic documentation field, but it is a subject of real interest, that includes indexing of films (using topic maps) to access them at sequence level. The next step on this would be to review the state of the art of this kind of movie databases.

Scripting capability is a feature that some platforms like Kmap support and that could be interesting to explore in the final implementation for more interactive implementation. It is not needed for collaboration because CmapServers and conventional hypertext links suffice for this application.

7 Summary

This article has described a new and open concept map-based hypermedia system for film analysis and film teaching (direction, narration). It uses Cmaps as navigational and conceptual structure for non-linear access and flexible interaction on multimedia materials for film analysis or study. Cmaps and Hypermedia fit very well with the objectives of the project to explore new ways of analyzing films. The methodological model and the demonstration and evaluation prototype being built were described. Standard and free widely available tools are used to enable universal use. Further tool evaluation and development is foreseen as it opens new and alternative paths for film analysis and communication.

8 Acknowledgements

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LOS MAPAS CONCEPTUALES COMO AGENTES FACILITADORES DEL DESARROLLO DE LA INTELIGENCIA EN ALUMNOS DE ENSEÑANZA PRIMARIA

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Resumen. El trabajo de investigación que presentamos tiene como objetivos evaluar la influencia que la construcción de mapas conceptuales, considerados como instrumentos de evaluación, enseñanza y aprendizaje, tienen en el desarrollo aprendizaje significativo frente al aprendizaje memorístico-mecánico(desgraciadamente predominante en la mayoría de los centros), y también valorar el desarrollo de la inteligencia experimentado por los alumnos y medido por el BADyG(Batería de Aptitudes Diferenciales y Generales. El estudió se centró en una muestra constituida por 43 alumnos pertenecientes al Ciclo Tercero de Enseñanza Primaria (cursos 5º y 6º, 10-12 años), de un Colegio Pública de Pamplona (España).
El análisis de la evolución de los mapas conceptuales construidos por los alumnos en tres fases: inicial individual, final individual y compartidos en grupos, muestra que los alumnos han aprendido significativamente y paralelamente a este hecho, los resultados obtenidos en la aplicación del BADyG demuestran que ha tenido lugar un incremento en la inteligencia, puesto en evidencia por la evolución del cociente intelectual (CI) y de la llamada inteligencia fluida.

1 Introducción

Es un hecho habitual constatar cómo cuando los docentes queremos evaluar lo que nuestros alumnos aprenden nos fijamos, casi exclusivamente, en los contenidos nuevos que han adquirido tras el trabajo realizado, e inadvertidamente, dirigimos todo el trabajo intelectual de los mismos hacia un aprendizaje mecánico-memorístico. Sin embargo, son muchos los autores que diferencian en el proceso de aprendizaje dos aspectos distintos: la adquisición de contenidos, resultado del hecho intencional de instrucción y el desarrollo de procesos cognitivos, libres de contenido (Brown y Campione, 1988; Butterfield, 1988; Sternberg, 1988). Es evidente que ambos procesos interactúan.

Teniendo en cuenta lo expuesto nos propusimos que los alumnos aprendieran significativamente y en consecuencia modificaran su estructura cognitiva. Los mapas conceptuales(MMCC) fueron el hilo conductor de la práctica educativa utilizándose para las evaluaciones inicial (control de los conocimientos previos) y final, así como para el aprendizaje. Construidos, en unos casos individualmente, en otros en pequeños grupos o colectivamente; permitieron que los alumnos fueran conscientes de sus propios conocimientos y de que compartieran y consensuaran los mismos.

Además de utilizar los mapas para evaluar los cambios que se producían en sus estructuras cognitivas, se empleó el test BADyG(Batería de Aptitudes Diferenciales y Generales) (Yuste, 2001). Esta batería de pruebas permite valorar lo que Cattell (1971) y Horn (1988) denominan **inteligencia fluida** (medida, fundamentalmente a través de los factores: Analogías verbales, Series numéricas y Matrices lógicas) e **inteligencia cristalizada,** que pueden ser relacionadas directamente con aprendizaje significativo y memorístico, respectivamente. Permite, así mismo, determinar el CI de los alumnos. Mediante su aplicación se podría comprobar la mejora de la inteligencia general y, sobre todo, de la inteligencia fluida.

2 Desarrollo de la investigación

2.1 Contexto

El trabajo de investigación que presentamos forma parte del llamado Proyecto GONCA (González y Cañas, 2003), financiado por el Departamento de Educación del Gobierno de Navarra y fue llevado a cabo durante dos cursos consecutivos en el Colegio Público José Mª Huarte. En la investigación tomaron parte 43 alumnos distribuidos en dos grupos A y B(con 22 y 21 alumnos, respectivamente) y correspondientes a Tercer Ciclo de Enseñanza Primaria(grado 5º y 6º,10-12 años). La adscripción de los alumnos a los dos grupos se hizo al azar; este dato, junto con los proporcionados por la praxis diaria de los procesos de enseñanza/ aprendizaje comunes, las opiniones de los profesores que imparten clase en ambos grupos, y las calificaciones medias similares en las distintas evaluaciones nos hacen pensar en su equivalencia. A mayor abundamiento ambos grupos presentaban características semejantes en cuanto a procedencia social, nivel cultural, características psicológicas y de escolarización. En ambos, además, se incorporaron a lo largo de la experiencia alumnos nuevos (inmigrantes, fundamentalmente) con distintos historiales educativos que les llevó a participar de forma irregular en la misma**.**

El proyecto se centró en el intento de que los alumnos aprendieran significativamente los contenidos propios de la Etapa, especialmente en el área de Matemáticas. Como ya se ha dicho anteriormente la construcción de MMCC tuvo un especial protagonismo en el proceso de aprendizaje, utilizándose complementariamente para su construcción el programa CmapTools (Cañas *et al.*, 2004) elaborado por el Profesor Cañas y su equipo del Institute for Human and Machine Cognition.

2.2 Metodología

En todo momento la experiencia fue guiada por los siguiente principios rectores:

- Que es el alumno quien aprende y sólo es él quien puede construir sus propios conocimientos.
- Que para que pueda llevarse a cabo un aprendizaje significativo (objetivo número uno de nuestro proyecto) hay que motivar al alumno para que quiera aprender de esta forma; así como facilitárselo proporcionándole materiales potencialmente significativos, basados en sus conocimientos previos y presentados adecuadamente ordenados (González y Novak, 1996).
- Y, todo ello, inmerso en un ambiente de cooperación, respeto, participación, ayuda..., que tan favorablemente contribuye a crear la elaboración de los mapas conceptuales por medio del software CmapTools.

Los materiales empleados fueron, además del ordenador, distintos útiles de medida (unidades de longitud, capacidad, masa...) dos libros de texto y cuadernos de actividades

En líneas generales se realizó teniendo en cuenta las siguientes fases:

1. Preparación del mapa de la instrucción, en colaboración con los otros dos miembros del proyecto que han trabajado en el área de Matemáticas (ver Fig.1).
2. Realización por parte de los alumnos de un mapa inicial con los siguientes conceptos: magnitudes, medida, comparación, unidades, forma compleja, longitud, capacidad, masa, tiempo, forma incompleja, naturales, sistema decimal, el palmo, el pie, el metro, el litro, el gramo, convencionales, múltiplos, submúltiplos, cambios, elemento a medir, sistema sexagesimal, el minuto, el segundo, la hora.
3. Evaluación inicial de los alumnos antes del periodo de instrucción.
4. Instrucción, propiamente dicha, señalando sus tres fases: **introducción, focalización y aplicación**.
5. Realización de un mapa conceptual (mapa intermedio) al finalizar la materia correspondiente a la medición de las magnitudes. Para su realización se empleó la misma relación de conceptos antes referida. A lo largo de la instrucción se puso especial cuidado en que los alumnos repararan y reflexionaran sobre los conceptos que se iban manejando, para ello fueron construyendo una lista con todos los que iban apareciendo, justificando su incorporación a la misma. Este mapa fue construido en grupos de dos - tres alumnos, utilizando el programa informático CmapTools. Esta forma de hacer (pequeños grupos) es habitual dado el extraordinario potencial de aprendizaje que supone compartir significados entre los alumnos, así como el valor añadido del trabajo cooperativo. Todo ello redunda en la creación en el aula de un clima interesante de cara al trabajo y las relaciones personales.
6. A los tres meses de finalizada la instrucción, los alumnos volvieron a realizar un nuevo mapa conceptual (mapa final), en este caso individual, acerca de la misma lista de conceptos. Con el paso del tiempo se trataba de minimizar la influencia de la memoria mecánica y así descubrir qué queda realmente en la memoria semántica del alumno tras el proceso de la instrucción, conocimientos que constituirán la estructura cognitiva previa para posteriores aprendizajes.

2.3 Resultados

En coherencia con los objetivos propuestos y para valorar el desarrollo de la inteligencia de los alumnos se aplicó el test BADyG, al comienzo y al final del ciclo educativo. Por razones puramente operativas se aplicó únicamente al grupo B. Los resultados se muestran en los gráficos de las Figuras 2 y 3.

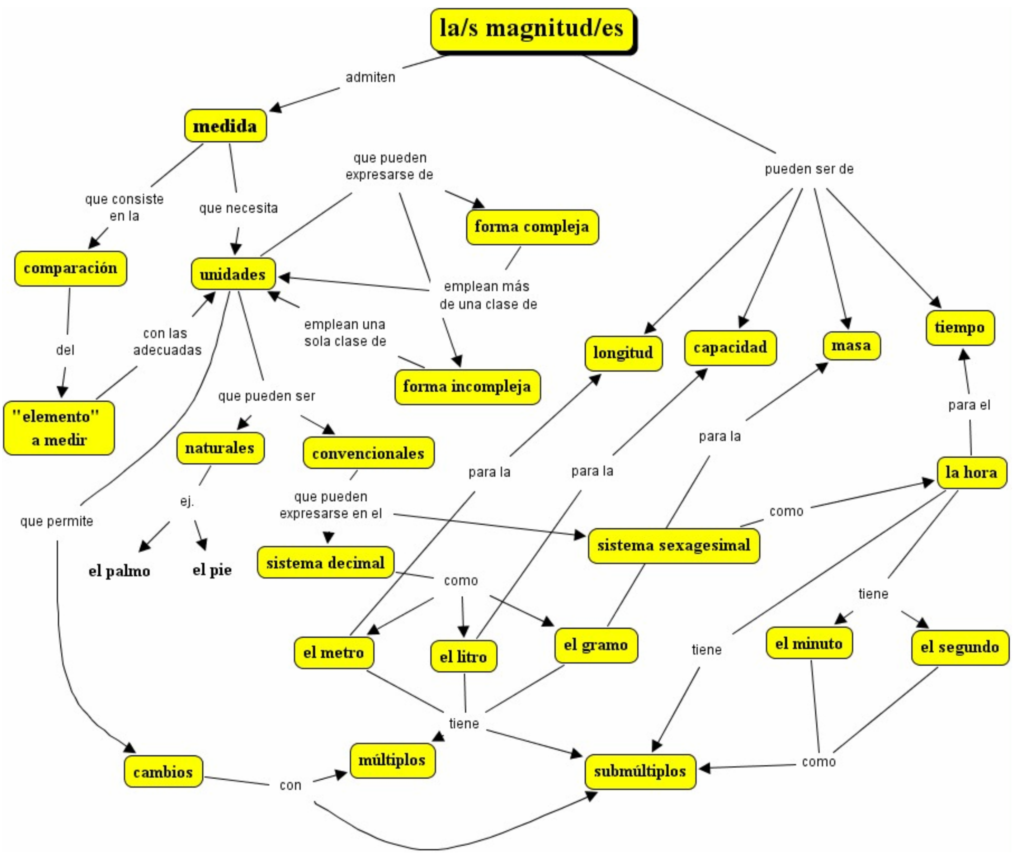

Figura 1. Mapa de la instrucción

De los aspectos que hemos estudiado en relación con la evolución de los MMCC realizados por los alumnos y que consideramos indicadores de un aprendizaje significativo (por ej.: utilización de conceptos, diferenciación de conceptos/términos de enlace, niveles jerárquicos definidos, número y calidad de las proposiciones, presencia de secuencias lineales, ordenación de lo general a lo específico, enlaces cruzados, etc.), hemos elegido como ejemplo la utilización de los conceptos en el proceso de aprendizaje (ver Tabla 1)

2.3.1 Inteligencia

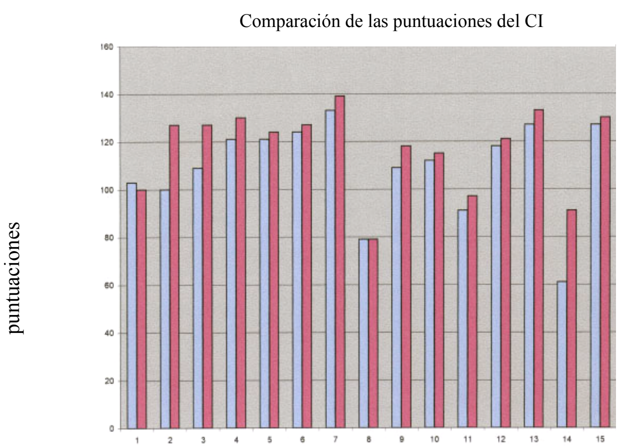

Figura 2

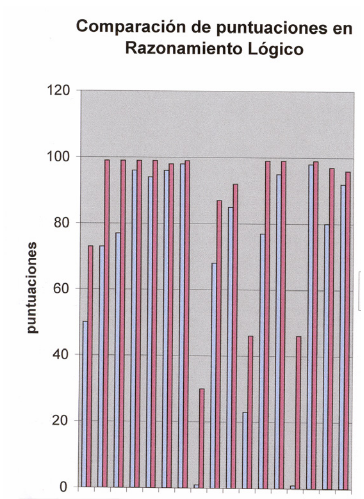

Figura 3

Antes de la instrucción

Después de la instrucción

En relación con los resultados de aplicación del BADyG, y, de forma general, cabe mencionarse:

- Que todos los alumnos, excepto dos, alcanzan mayor puntuación en Inteligencia General al finalizar el Ciclo; siendo en conjunto las diferencias muy significativas (0,004)
- Que todos los estudiantes mejoran significativamente en Razonamiento Lógico (inteligencia fluida).

2.4 Aprendizaje significativo

Ya se ha significado con anterioridad que de entre todos los aspectos que pueden ser valorados en un mapa conceptual como indicador de aprendizaje significativo, nos hemos centrado en los conceptos. Para la realización de los tres mapas (individual inicial y final, y el compartido en grupo) se propuso a los alumnos exactamente la misma lista de conceptos.

Si tenemos en cuenta el número de conceptos empleados, en todos los casos, excepto una alumna, los mapas finales contienen un mayor número de ellos.

En el primer mapa, once alumnos emplean menos de la mitad de los propuestos (entre 7 y 13); utilizando, el resto, más de la mitad (entre 14 y 21) (media = 15,2).

En el segundo, sólo dos alumnos emplean menos de la mitad, usando el resto entre 14 y 26 (media = 21,8).

En el mapa que elaboran conjuntamente utilizan un número de conceptos semejante al mapa final (media = 22,6).

Da la impresión de que la actitud de los alumnos al inicio y al final cambia. Así, mientras para la construcción del primer mapa seleccionan aquellos conceptos de los que se sienten capaces de decir algo, en el final se obsesionan con la idea de tener que incluirlos todos (en varias ocasiones los alumnos manifiestan tal preocupación o su satisfacción por haber sido capaces de emplearlos en su totalidad). Puede, en este segundo caso, que se sientan en la "obligación" de utilizarlos puesto que todos ellos han sido manejados durante la instrucción. Esta necesidad de incorporar todos los conceptos les lleva a buscar explicaciones "ad hoc" o forzadas, al margen del contenido de la materia.

Hay, en el mapa final, una mayor incorporación de conceptos nuevos y de ejemplos no referidos en la relación, así como una mayor tendencia a abundar en informaciones conocidas.

En los mapas colectivos emplean, tal y como ha quedado dicho antes, un número de conceptos ligeramente superior al de los mapas finales. Se aprecia en los primeros, sin duda como consecuencia de la inmediatez de su construcción respecto de la instrucción, una mejor colocación y explicaciones más acertadas para los conceptos de inclusión media (unidades, sistemas de numeración, etc.). Esta información más abstracta y en algunos casos más difícil de aprender parece desaparecer con el paso del tiempo.

Pasaremos a continuación a considerar las características de los conceptos empleados y no empleados en los mapas inicial, final y compartido (ver Tabla 1).

A la vista de los conceptos empleados para la construcción del mapa inicial cabe hacer las siguientes consideraciones:

1º. Podemos distinguir cinco grandes grupos. El primero estaría formado por aquellos conceptos que se incorporan en pocas ocasiones (menos de 20 %), estos son: *comparación*, *forma compleja*, *forma incompleja*, *naturales*, *convencionales*, *cambios* y *elemento a medir*. Todos ellos parecen no resultar significativos en el contexto de la disciplina que nos ocupa.
2º. Un segundo grupo, utilizados por el 50% de los alumnos aproximadamente, son: *magnitudes*, *sistema decimal*, *sistema sexagesimal*, *múltiplos* y *submúltiplos*. Se trata de conceptos muy asociados al tema de la medida y con los que el alumno (exceptuando magnitudes) debería estar familiarizado.
3º. Un concepto, *unidades*, que es incorporado en sus mapas por el 70% de los alumnos. Este lo consideramos clave al hablar de medida y en él se hace, o se debiera hacer, hincapié en el área de matemáticas, tratado en sentido conceptual y no sólo mecanizado como ocurre habitualmente.
4º. *Medida* es usado por el 80 % de los alumnos.
5º. Y por último, conceptos como *longitud*, *capacidad*, *masa*, *tiempo*, *el palmo*, *el pie*, *metro*, *litro*, *gramo*, *minuto*, *segundo*, *hora*, son empleados por más del 85 % de los alumnos. Son, sin duda, los conceptos más concretos, más cercanos, aunque esto no debe presuponer que sean incorporados significativamente al mapa.

Tabla 1. Número de alumnos que no incorpora cada uno de los conceptos en los cada uno de los mapas: inicial, final y compartido.

	Mapa inicial		Mapa final		Mapa compartido	
Conceptos	**número**	**porcentaje**	**número**	**porcentaje**	**número**	**porcentaje**
magnitudes	18	46%	2	5,26%	0	0%
medida	8	20,5%	2	5,26%	4	23,5%
comparación	36	92,3%	23	60,5%	12	12%
unidades	12	30,7%	5	13,15%	1	6%
forma compleja	32	82%	7	18,42%	1	6%
forma incompleja	32	82%	5	13,15%	1	6%
longitud	1	2,5%	3	7,9%	0	0
capacidad	5	12,8%	3	7,9%	0	0
masa	6	15,4%	3	7,9%	0	0
tiempo	4	10,25%	1	2,6%	0	0
naturales	38	97,4%	15	39,5%	4	23,5%
convencio-nales	35	89,7%	15	39,5%	5	30%
sistema decimal	23	59%	6	15,8%	0	0
sistema sexagesimal	19	48,7	3	3,9%	0	0
el palmo	6	15,39%	2	5,26%	2	12%
el pie	5	12,6%	2	5,26%	2	12%
el metro	3	7,7%	1	2,6%	0	0
el litro	3	7,7%	2	5,26%	0	0
el gramo	2	5.13%	2	5,26%	0	0
múltiplos	24	61,5%	7	18,42%	3	18%
submúltiplos	23	59%	7	18,42%	3	18%
cambios	35	89,7%	12	31,6%	8	47%
elemento a medir	33	84,6%	14	36,8%	2	12%
minuto	4	10,25%	0	0	1	6%
segundo	4	10,25%	1	2,63%	1	6%
hora	5	12,8%	0	0	0	0

El panorama cambia casi totalmente al considerar los mapas finales; todos los conceptos, excepto comparación, son utilizados por más del 60 % de los alumnos. Cabe, también en este caso, señalar distintos grupos:

1º. El que correspondería al formado únicamente por el concepto *comparación*, utilizado por menos del 60 % de los alumnos. Es éste, sin duda, uno de los conceptos más abstractos que incluía la lista. Parece quedar claro que para los alumnos de esta edad resulta muy difícil explicar lo que supone medir. Intuitivamente lo hacen, son conscientes de la necesidad de una unidad adecuada al elemento a medir y a la que se le atribuye la cualidad de fiable, pero no son capaces de expresar el proceso mismo.

2º. El formado por los conceptos: *naturales*, *convencionales*, *cambios* y *elemento a medir*. Estos siguen siendo, al igual que ocurría en el mapa inicial, de los menos utilizados. En este grupo no aparecen ya *forma compleja* e *incompleja*, que pasan a ser incorporados por un mayor número de alumnos. Sorprende que los conceptos *naturales* y *convencionales* sigan siendo de los menos seleccionados ya que a lo largo del proceso de instrucción se hizo mucho hincapié en ellos, se comentó ampliamente la desventaja del uso de medidas naturales (poca fiabilidad) y parecía ser algo que los alumnos comprendían con absoluta naturalidad.

3º. Igualmente sorprende que el concepto *cambios* sea aplicado por muy pocos alumnos al de *unidades*, a pesar de que gran parte de la instrucción se dedica a hacer tal tipo de operación. Los resultados obtenidos en las pruebas convencionales ponen de manifiesto que los alumnos manejan los cambios con soltura, ahora bien cabe preguntarnos ¿realmente dan significado a lo que hacen?

4º. Entre un 80 y un 90 por ciento de los alumnos utilizan en sus mapas los siguientes conceptos: *unidades*, *forma compleja*, *forma incompleja*, *longitud*, *capacidad*, *masa*, *sistema decimal*, *sistema sexagesimal*, *múltiplos* y *submúltiplos*.

5º. Los demás conceptos: *magnitudes*, *medida*, *tiempo*, *el palmo*, *el pie*, *gramo*, *minuto* y *segundo* son incorporados por más del 95 % de los alumnos; alcanzando el 100 % en los dos últimos. Exceptuando *magnitudes*, que por cierto sólo en contadas ocasiones es definida como "lo que admite medida", los demás conceptos de este grupo coinciden con los que se incluían en el de más utilizados en el primer mapa.

No queremos dejar de comentar, tal y como ya se ha apuntado anteriormente, el hecho de que la incorporación de un concepto a un mapa suponga una utilización correcta del mismo, ya que con frecuencia, los alumnos dan explicaciones que no se corresponden con la lógica de la disciplina e incluso se sacan del contexto. Cabe destacar como ejemplo significativo la incorporación de *cambio*, por parte de un alumno, pero refiriéndose al cambio meteorológico.

En los mapas construidos en grupo aparece *comparación* como menos utilizado –sólo lo incorporan un 30 % de los alumnos- seguido de *cambios* (el 53 % lo usan). Un 70 % usan *convencionales, medida*, *naturales*, *múltiplos* y *submúltiplos* son empleados por un 80 % y el resto de los conceptos se distribuyen entre un 95 % (*unidades*, *forma compleja*, *forma incompleja*, *minuto* y *segundo*) y un 100 % para los demás: *magnitudes*, *longitud*, *capacidad*, *masa*, *tiempo*, sis*tema decimal*, *sistema sexagesimal*, el *metro*, el *litro*, el *gramo* y *la hora*.

3 Conclusiones.

- La comparación de los resultados obtenidos en las dos aplicaciones del BADyG muestra que se ha producido un aumento significativo de la inteligencia general.

- En dos de las tres pruebas que miden la inteligencia fluida (Relaciones analógicas y Series numéricas) se obtienen, así mismo, incrementos significativos. Esto anima a pensar que el aprendizaje significativo, basado en gran medida en el empleo de los mapas conceptuales, contribuye al desarrollo de las estrategias y procesos de aprendizaje.

- La evolución de los mapas realizados por los alumnos ponen de manifiesto evidentes mejorías. Si consideramos los mapas como un reflejo de la forma en que los alumnos tienen estructurado el conocimiento, podemos afirmar que ahora conocen más y sobre todo mejor. Situándose los alumnos en mejor situación y disposición para futuros aprendizajes.

- La utilización del CmapTools software ha implicado activamente al alumnado en la elaboración de conocimiento, al facilitar el aprendizaje colaborativo y la construcción social de aquel. Así lo demuestra la mayor calidad de los mapas realizados en equipo.

- Finalmente como valor añadido podemos señalar que la realización de los mapas conceptuales mediante ordenador y el hecho de poder compartir significados, han generado en los alumnos una disposición emocional/actitudinal positiva hacia el aprendizaje y consecuentemente, un desarrollo de conductas, en clase, apropiadas. Además se ha detectado, en varios casos, una implicación de las familias en este proceso.

4 Agradecimientos

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USING CONCEPT MAPS AS A RESEARCH TOOL IN SCIENCE EDUCATION RESEARCH

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Abstract. Concept maps were initially developed as a data analysis tool in Novak's research program. In his twelve-year longitudinal study Novak and his research group constructed concept maps to represent changes in children's understanding of science concepts. Since their development, concept maps have been widely used for many purposes and in many different contexts. Concept maps are most well known as metacognitive tools that facilitate student meaningful learning. In our own research programs, we continue to use concept maps in the context for which they were developed -- as a research tool to analyze data. This paper describes our use of concept maps in four research studies. In the first, concept maps were used as a tool for analyzing interview data of students' understanding of ecological processes over a six-year period. In the second, concept maps are being used to compare individual students' understandings of the transformation of matter with students' shared understandings. In the third study, concept maps were used as a research tool by a team of research scientists. They were found to help some members of the team to identify research questions that guided their individual research project. The fourth study, is using concept maps to investigate the development of students' conceptual understanding of science in environmental problem solving-based courses at colleges and universities across the U.S.

1 Introduction

Gowin's and Novak's early work on the nature of knowledge and learning explored factors that influence students' understanding of science and the acquisition of concept meanings (Novak, 1998; Novak & Gowin, 1984). Together their research programs led to the development of two metacognitive tools – Vee diagrams and concept maps. Gowin developed his Vee heuristic to help students studying science make explicit twelve elements essential to constructing scientific knowledge (Gowin, 1981; Novak & Gowin, 1984). Concept mapping grew out of Novak's research program when a tool was needed to represent changes in children's understanding of science concepts over a twelve-year period. This data analysis tool would have to have both simplicity and high specificity (Novak & Musonda, 1991). A concept map visually represents knowledge as a hierarchical framework of concepts and concept relationships. Concept maps are rooted, in part, in epistemological ideas expressed in Gowin's Vee, wherein concept meanings are constructed through human perceptions and interactions with objects and events in the world.

Since their development, concept maps have been widely used for many purposes and in many different contexts. They are most well known to science education researchers and teachers as a metacognitive tool that helps students understand the science they study. Concept maps have also been shown to be useful for (a) providing a summary of a person's existing knowledge, (b) identifying misconceptions, (c) revealing gaps in understanding, (d) promoting reflective thinking, (e) designing curricula and instructional materials, (f) assessing student learning, (g) evaluating program effectiveness, (h) facilitating communication and arriving at shared understandings among members of groups, (i) understanding the processes by which scientists construct new knowledge, and (j) studying problems in epistemological foundations and assumptions (Mintzes, Wandersee & Novak, 1999 & 2000; Novak, 1998; Novak & Gowin, 1984).

Though concept maps have come to be used for many different purposes, we continue to use them in the manner for which they were initially developed, that as a research tool. This paper describes our use of concept maps in our respective research programs. We present narratives of the paths we each took to coming to use concept maps as a research tool. Then we present examples of concept maps drawn from our research.

2 Concept Maps As Research Tools: Contexts and Applications

2.1 A Longitudinal Study of Students' Understanding of Ecological Processes

Over a period of many years teaching biology, I found that students at different ages had difficulties describing, in their own words, how biomass builds up and breaks down. They also had difficulty in describing where matter comes from and where it goes. I have also found students, when discussing general environmental issues, to have limited knowledge about concepts concerning transformations of matter, such as decomposition and combustion. Could their lack of knowledge be due to the fact that teaching has not been based on students' thinking about ecological phenomena? In order to create teaching situations during which students′ ideas about natural phenomena can be challenged, educators must understand how students' thinking about different phenomena develops over time. Therefore, I conducted a longitudinal study of the development of 24 students' understanding of ecological processes from the age of 9 to 15. These ecological processes comprised dealing with conditions for growth, decomposition in nature, and the role of the flower in plant reproduction (Helldén, 1995; Helldén,1999; Helldén, 2004).

I, like many other science education researchers, have found that clinical interviews can give in depth information on students' thinking about natural phenomena (Duit, Treagust & Mansfield, 1996). I interviewed the students on eleven occasions about the three ecological processes. During the interviews I made it clear to them that I was interested in their thoughts per se, not whether their responses were right or wrong. To show the students that I was primarily interested in their thinking, I usually started the first interview question with the words: "What do you think ....?" The interviews were carried out at a small, Swedish primary school and later at a larger lower secondary school with more subject-oriented teaching. Over the course of my study I interviewed the same twenty-four students concerning ecological processes from grade 2 (9 y), with additional students being included to form a stable population of twenty-nine students from grade 4 (11 y) to grade 8 (15 y). The timing of the interviews was complex, but generally occurred in cycles of 1-2 years for each ecological phenomenon. All of the students belonged to the same class for all that time, an unusual feature that reflects the stability of the population in this area in Sweden.

All of the interviews were audiotaped and transcribed verbatim before analysis started. There was a great deal of material to transcribe and analyze. I was not satisfied with the Piaget-inspired analysis that I had been introduced to. After reading *A Theory of Education* by Novak (1977) I became interested in Ausubel's theory of meaningful learning. I met Professor Novak at the Third International Misconception Seminar in Science and Math at Cornell University in 1993. He invited me to spend a semester at Cornell in order work with my interview data. When I came to Cornell in August 1995, I brought all of my interview tapes and transcripts with me but I had not yet found a solid theoretical foundation for my analysis of the interviews. I became involved in fruitful discussions during seminars with Professor Novak's research group. As a result of these discussions, I realised that the development of the students' understandings could be usefully described as a progressive differentiation through which new concepts are subsumed under concepts that already exist in the learner's thinking (Ausubel, Novak, & Hanesian, 1978).

As I began my in-depth analysis of interview data I was faced with the problem of the large amount of interview transcripts that I had to analyze. At this stage I began to construct concept maps of the interviews similar to the methods used by Novak's research group in their twelve year longitudinal study of students' understanding of the particulate nature of matter (Novak & Musonda, 1991). I read the interview transcripts carefully again and again, and I marked the concepts that the students used in responding to my interview questions. I then built a hierarchy according to the students' expressions, starting with the concepts we discussed, for example the needs of plants' placed in a sealed transparent box. By comparing concept maps of the same student at different ages, I could develop an explicit picture of the student's conceptual development. The concept maps visually represented the pathways used by the students to describe and explain the ecological phenomena. Thus I could see how the students developed their understandings by subsuming new concepts under those already present in their cognitive structure.

In Figures 1-3, we can follow how one student, Oscar, developed his understanding about conditions for growth of plants placed in a sealed transparent plastic box. Oscar did not mention anything about water at 10 years of age. When he was 13 he realized that the plant needs water and thought it came from the soil. At 15 years of age he expressed a more complete picture and had subsumed the concepts of evaporation and condensation under the concept of water. We can also follow how Oscar changed his ideas about oxygen. In Figure 1 we can see how he claimed that the plant needed oxygen and that the oxygen would disappear. At 13 years of age he suggested that the plant got its oxygen from the soil. When Oscar was 15 he did not at all talk about any need for oxygen but argued that oxygen was a result of the superordinate concept photosynthesis.

In all of the interviews about conditions for growth, Oscar said that there must be invertebrates like earthworms in the soil. When he was 15 years of age he claimed that the plants in the box had to breathe in

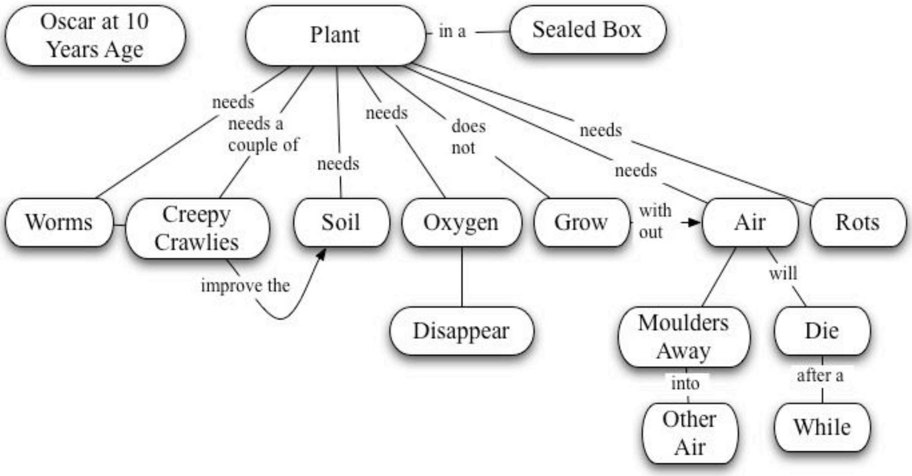

Figure 1. Concept map developed from an interview with Oscar at 10 years of age about conditions for life needed by plants placed in a sealed transparent box.

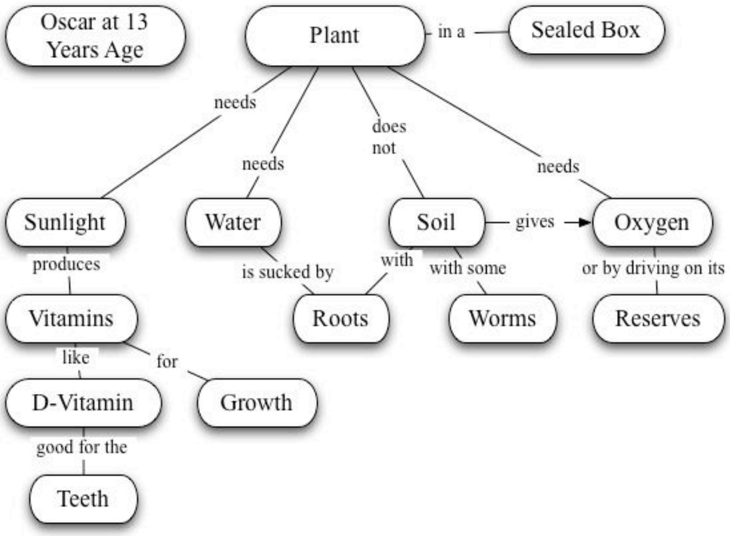

Figure 2. Concept map developed from an interview with Oscar at 13 years of age about conditions for life needed by plants placed in a sealed transparent box.

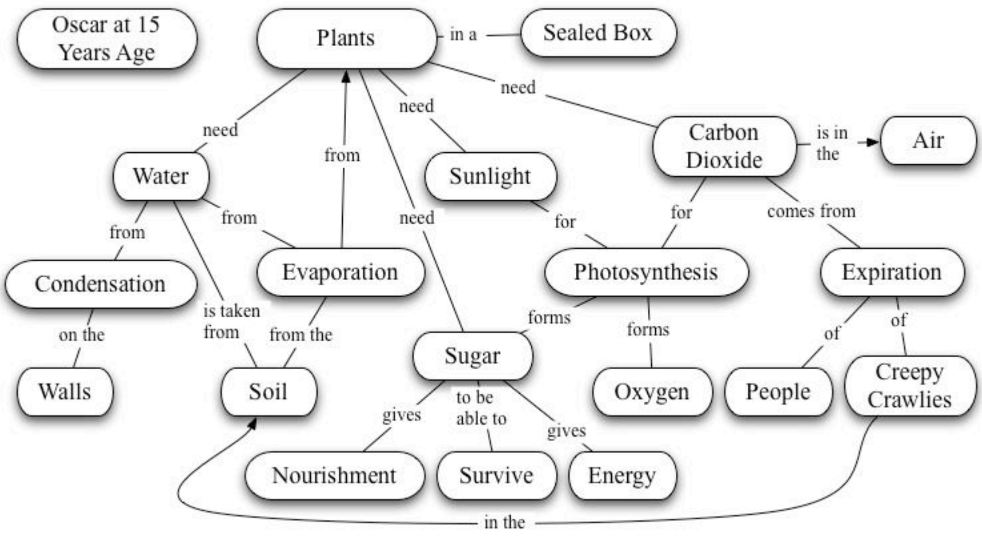

Figure 3. Concept map developed from an interview with Oscar at 15 years of age about conditions for life needed by plants placed in a sealed transparent box.

carbon dioxide, but he had problems explaining from where it came. After a while he said, *"Ah, there must be soil invertebrates in the soil, and they release carbon dioxide that the plants can use."* An integrative reconciliation had occurred. His idea since five years about the need of invertebrates was attached to the need of carbon dioxide for photosynthesis. A new relationship was established in his cognitive structure. By comparing concept maps from interviews at different ages it has been possible to identify personal key ideas that appeared in the interviews through the years like Oscar's mention of soil invertebrates.

2.2 Students' Shared Understandings of the Transformation of Matter

Our most current recent research in Kristianstad is a longitudinal study of the development of students' understanding, from age 7 to 16, about transformations of matter in three different contexts: (1) decomposition of leaves on the ground; (2) a burning candle; and (3) condensation inside a glass-jar (Holgersson & Löfgren, 2004). The students were interviewed individually every year about these examples of transformations of matter. We also wanted to know how the students shared their understandings with other students. Therefore, we decided to let the students first make a concept map of their own. After we had copied the individual concept maps, we let the students discuss with each other the ideas represented in their concept maps. Figures 4 and 5 are examples of two student's individual concept maps on what happens to a burning candle. Figure 6 is a collaborative map on the same topic constructed by three students. These 10-year-old students were familiar with concept mapping and we asked them to construct maps using the following concepts: heat, flame, fire, molecule, but they were permitted to use as many other concepts as they wanted.

We can see in the following concept maps that there are contributions from the individual maps to the construction of the common concept map. There were only a couple of concepts that they had not in common according to the individual concept maps. The concept map that they have done together contains more connections between the concept of molecule and other concepts than the individual concept maps. It also shows the problems have to understand the difference between matter and energy (heat). The discussions during the construction of their map challenge them to talk about the colours of the flame. The concept maps from different groups of students with their shared understanding became an important resource for the design of the next step in our research project. It also became obvious that concept maps with shared understanding can be successfully used in schools.

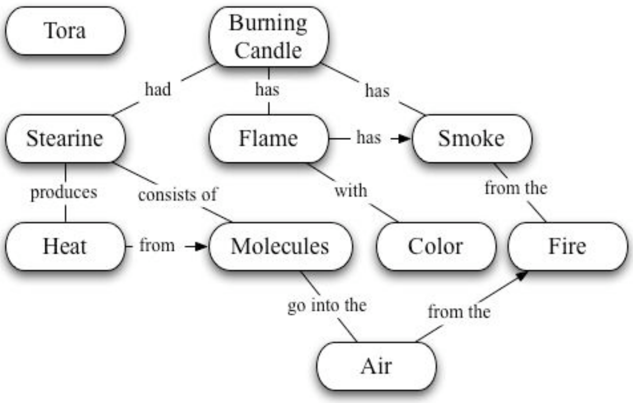

Figure 4. Tora's individual concept map for a burning candle.

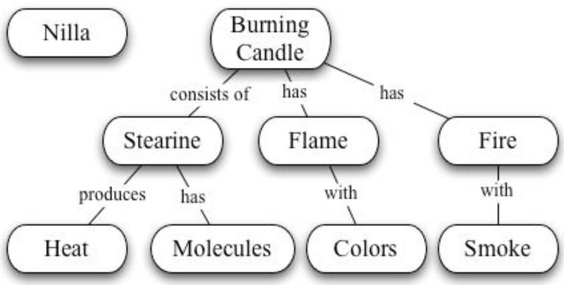

Figure 5. Nilla's individual concept map for a burning candle.

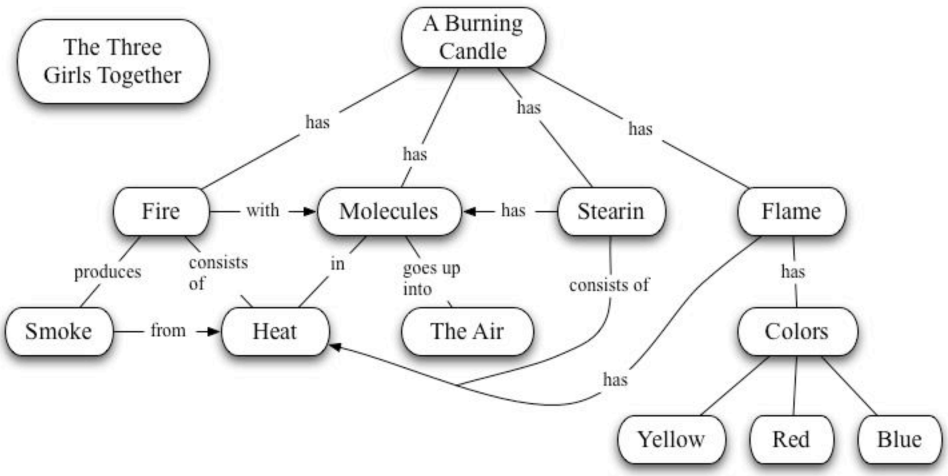

Figure 6. Tora's, Nilla's and Sofie's collaborative concept map for a burning candle.

2.3 The Use of Metacognitive Tools in a Multidimensional Research Project

During my fourth year into my doctoral studies in plant pathology at Cornell University I had the opportunity to enroll in an education course to explore my emerging interest in teaching science. That course, Learning to Learn, was taught by Joe Novak. I had never before heard of constructivism, meaningful learning, concept mapping, nor most of the concepts and principles presented in the course. It was all new to me, however, it was all very exciting. The experiences and knowledge I gained in the course changed my whole outlook on life and the direction I was headed. With Joe's encouragement and support, I left my program in plant pathology and began my doctoral studies in science education under the mentorship of Joe Novak.

My experiences conducting science research together with my developing understanding of human learning led me to my world view that it is essential for scientists to have an understanding of the nature of knowledge and scientific inquiry if they are to be exemplary researchers and teachers. Only then will they be empowered to facilitate their own, and their students', meaningful learning; and only then will they have the creative insight to make quantum leaps in our understanding of objects and events in the natural world. Throughout her research career, Nobel laureate Barbara McClintock demonstrated that personal convictions on the nature of knowledge extend beyond the cognitive domain (Iuli, 1998). For her, research was filled with emotions. She could not divorce herself from this essence of being human. It was clear to her that cognition and affect, thinking and feeling, could not be divorced from one another, no matter how "objective" a person tries to be.

The success of metacognitive tools in educational settings suggested to me that they may help scientists organize and construct knowledge; thereby facilitating their research activities and enhancing their understanding of the events and objects they study (Iuli, 1998). This research study investigated how members of a multidimensional team of research scientists (the USDA Rhizobotany Project) constructed and organized knowledge (Iuli, 1998; Novak & Iuli, 1995).

A fundamental problem of conducting interdisciplinary research, working in collaborative groups, and teaching and learning in classroom environments is communication and arriving at a shared understanding among members of the group. Thus one way in which I used concept maps in my research was as a tool to help members of the Rhizobotany Project arrive at a shared understanding of the overarching goals of their work and how each individual's piece fit within the larger puzzle.

At times during my research there were some exciting moments when I thought that members of the research team saw the global picture of the Rhizobotany Project and the connections among the different areas of research being explored. One of these moments occurred early on in my work with the team. Figure 7 shows a concept map for the multidimensional research efforts of the Rhizobotany Project. This global map was constructed by the team, including myself, following a weekly Project meeting devoted to brainstorming. The project director's opening comments to the research team at the start of the brainstorming session were, "One of the things we are brainstorming for is a first step priority concept map to figure out where we are going next. The work we are going to be doing for the next five years or more is dependent upon the information that [we will discuss today]." Though the team was able to arrive at a shared understanding of the goals and aims of the

Rhizobotany Project, some members of the team, in their own area of work, were unable to keep this global perspective in mind. They were working in, what I called, conceptual isolation.

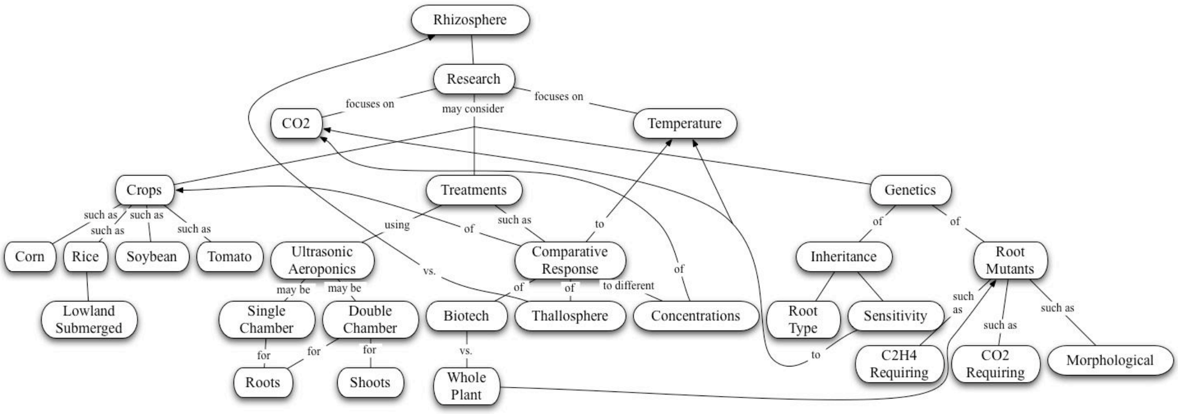

Figure 7. Concept map showing areas of research being conducted by scientists of the Rhizobotany Project.

During the two and one half years of this naturalistic study I found that some members of the team used concept maps to help define their research questions, design experiments, and identify key links between their individual research and that of other members of the team. Figure 8 is an example of one researcher's concept map. Concept maps, such as this one, that Brad constructed from his existing knowledge of plant root-soil interactions served to guide his research on root morphological responses to acid and compacted soil layers. In constructing his map, he was able to articulate questions that helped to guide his research.

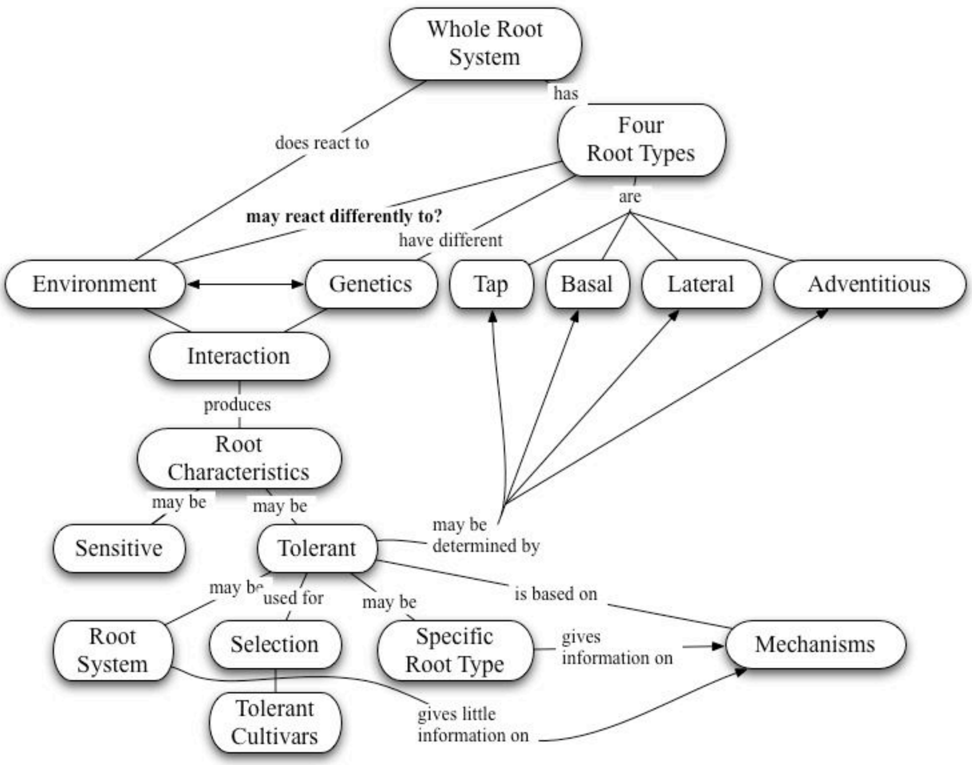

Figure 8. Brad's concept map that he constructed to guide his own research within the context of the Rhizobotany Project.

2.4 Assessing Student Conceptual Development in the NSF-Funded Regional Workshop Project

The National Science Foundation Regional Workshop Project is a national dissemination project that provides training to nearly 400 college and university science faculty across the U.S. in the use of an environmental problem solving (EPS) model to teach university-level science courses. Our current research focuses on investigating the effectiveness of the Regional Workshop Project. Two goals of our research are (1) to evaluate faculties' capacity to adapt the EPS model to their undergraduate science courses and (2) to assess their students' conceptual development of science over the course of a semester in EPS-based courses. Concept maps are our primary research tool for helping course faculty to identify key concepts and concept relationships that they expect students to learn and for assessing student conceptual development in their EPS-based courses.

One year after faculty participate in a Regional Workshop, we interview selected case study faculty about key concepts and concept relationships that they expect their students to learn in their EPS-based course. The interview tapes are transcribed and our research team constructs concept maps of the faculty interviews. These expert-level concept maps are used for two purposes. First, they are used to develop pre-and post-instruction interview guides for student interviews, Second, the expert-level maps serve as a benchmark against which concept maps constructed from student interviews are compared for quality and quantity of understanding.

We select and interview 10 students in each case study faculty's science course. Students are interviewed pre- and post-instruction. The interview tapes are transcribed and we again construct concept maps from the interview transcripts. Data analysis of student concept maps addresses both ipsative comparisons (examining the change in conceptual understanding from the beginning to the end of semester for each student) as well as criterion-referenced comparisons (examining the similarity of the student maps to a faculty "expert" map at the beginning and end of semester). We closely examine maps for accuracy by calculating the percentage of correct propositions in the faculty map that are also present in the student map. The percentages of correct propositions in the student map are compared at the beginning and end of semester to indicate a measure of growth in conceptual understanding.

Figure 9 is a concept map constructed from a faculty interview. In addition to helping the faculty clearly identify what it is s/he expects students to learn in their course, such expert-level maps are used as benchmark against which to compare pre- and post- instruction student maps.

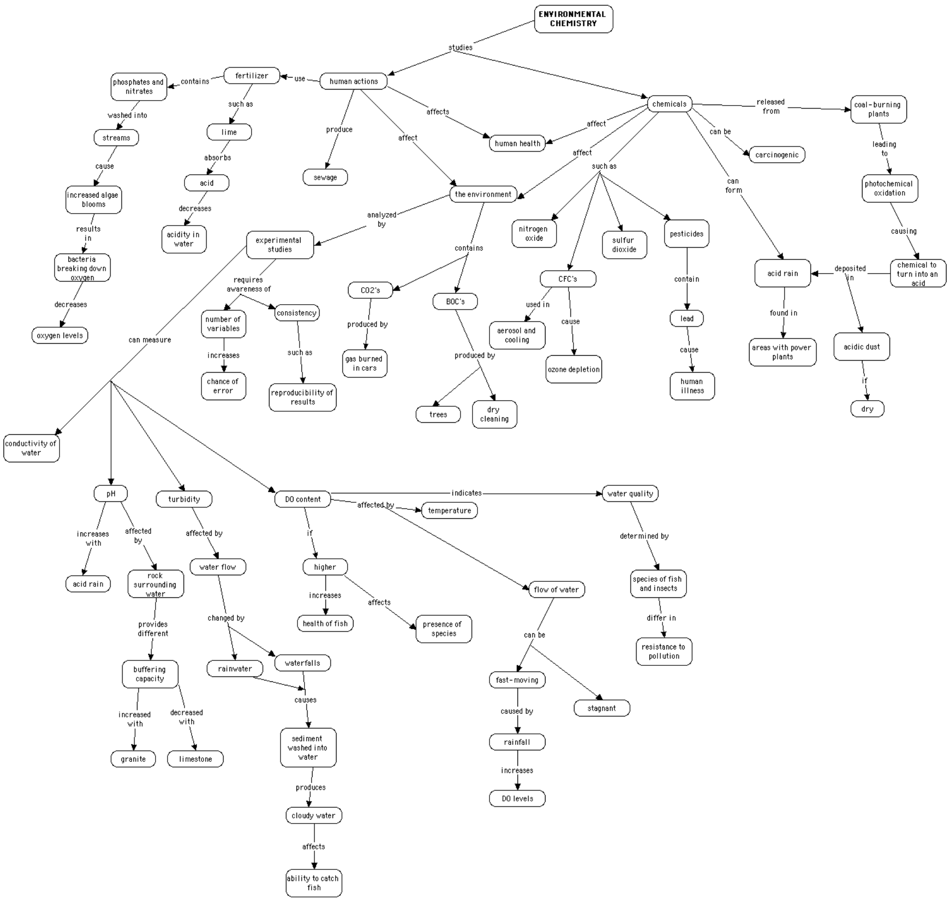

Figure 9. Concept map constructed from faculty interview. This concept map is used to develop the pre- and post-instruction student interview guides and as a benchmark for comparing concept maps of student interviews.

3 Summary

In our own research programs we continue to use concept maps primarily as a research tool – the very purpose for which they were initially developed. We have presented brief descriptions along with example concept maps from four of our research studies. In the first, *A Longitudinal Study of Students' Understanding of Ecological Processes,* concept maps were used to track the development of students' understanding of ecological processes from age 9 to 15. Concept maps were used to analyze interview data over this six-year period. In the second, *Students' Shared Understandings of the Transformation of Matter,* concept maps were used to compare individual students' understandings of concepts relating to the transformation of matter with students' shared understandings. Students first constructed individual concept maps. After viewing and discussing one another's' maps, students constructed a collaborative map that reflected their shared understandings. Comparison of individual and collaborative maps showed that students had difficulty differentiating "matter" and "energy".

In the study, *The Use of Metacognitive Tools in a Multidimensional Research Project,* concept maps were used as a research tool by a team of research scientists. They were shown to help the research team construct a global blueprint of their research efforts. They also helped some members of the team to identify research questions that guided their individual research project. The fourth study, *Assessing Student Conceptual Development in the NSF-Funded Regional Workshop Project,* uses concept maps to investigate the development of students' conceptual understanding of science in environmental problem solving-based courses at colleges and universities across the U.S.. Individual student concept maps, constructed from pre- and post-instruction interviews, are compared to one another for growth in quality and quantity of understanding. They are also compared with faculty concept maps for scientific accuracy and depth of understanding.

4 Acknowledgements

The project *Assessing Student Conceptual Development in the NSF-Funded Regional Workshop Project* is supported by a grant from the National Science Foundation (DUE0127725). We wish to thank our dear friend and colleague, Joe Novak, for making all of this possible. His influence on our work has been profound.

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HOW TO ACQUIRE "THE HABIT OF CHANGING HABITS": THE MARRIAGE OF CHARLES PEIRCE'S SEMIOTIC PARADIGM AND CONCEPT MAPPING

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Abstract: This paper grapples with the problem of how to track a student's real progress in learning, which cannot be absolutely quantified at any given point as a result of a particular intervention. Here, only some results are presented for a long-term qualitative and quantitative classroom study, during which the method of concept mapping was applied and interpreted in light of the semiotic paradigm developed by Charles Sanders Peirce (1931–1958). Peirce's semiotic paradigm was thought to have sufficient rigour and flexibility to give new access to the multiplicity of processes at work in the classroom.
A natural learning environment was built over a four-year period in a Finnish primary school. The students, ranging in age from 9 to 12 years, were encouraged to use qualitative judgement (intuition, tacit knowledge) to give them greater intellectual access to the meanings of the concepts taught. The goal was to bring them to Vygotsky's stage of 'conceptual learning', and to evaluate the effectiveness of concept mapping as an 'advance organiser' used in conjunction with Peirce's semiotic paradigm.
This paper concentrates on the theory building of concept mapping. However, the four-year longitudinal study results (Kankkunen 1999; 2001) show that concept mapping provided a means for students to discover tentative meanings for the concepts taught. In parallel, Peirce's semiotic paradigm provided a pragmatic framework for tracking the process of 'updating meanings' (the habit of changing habits) which is intrinsic to learning. The marriage of Peircean theory and concept mapping is lasting.
Keywords: abductive reasoning, concept mapping, connection-making, establishing meaning, learning environment for understanding, longitudinal study, students as evaluators

1 Introduction

Concept mapping is an effective 'advance organiser' for learning in the classroom. One of its key strengths is how it helps the teacher track a student's conceptual development in relation to the curriculum. Another is how it keeps the teacher focused on the process of meaning-making. The goal is to bring the student to Vigotsky's (1962) stage of 'conceptual learning', whatever his or her intellectual ability level is. In reaching this goal, the founder of concept mapping, Joseph D. Novak (e.g. 1992) said 'less is more'. That is, it is better for the student to understand 'completely' a handful of important concepts than to misunderstand a hundred lesser ones. The central hypothesis of this article is that concept mapping – a consciously artificial and pragmatic method of visualising thinking – helps students to recognise the reasoning process and control it on the road to conceptual learning.

2 In Search of a Third Dimension

"In point of fact, human semiosis and education are one and the same thing; that is, if by semiosis we mean the lifelong building of structures of experience, then education is precisely that field which attempts to understand, nurture and make people more reflective about this process." (Cunningham, 1987, p. 197)

Michael Apple (1999) reminds us that there is no one-to-one correspondence between psychological theory and educational theory. I was left wondering if a theory could be found which could better handle the human complexity of the meaning-making process in the classroom. In other words, a third dimension was needed to illuminate the existing two dimensions: a concept's 'perceived regularity' and its meaning as 'propositions and concept labels in a semantic unit'. Novak himself has touched upon the need for this third dimension when referring to the student's *innate capacity* to sort out concepts. If such a third dimension could be found to provide a framework for understanding the 'connection-making of meaning-making', it would be very useful in evaluating students' individual learning for understanding in the social classroom context.

3 Peirce's Semiotic Paradigm: The Third Dimension

Charles Sanders Peirce (1931–1958) developed a semiotic paradigm which describes how people construct an understanding of reality. In the long-term project on which this paper is based, this semiotic paradigm provided the third dimension ('connection-making') that was lacking in the preliminary study. The theory of building meaning applied in this paper is based on Peirce's semiotic paradigm and pragmatic approach. Its use of abductive reasoning in relation to learning is also based on Peirce. Throughout his discourse on semiosis and logic, Peirce emphasises the importance of the social community in constructing knowledge (i.e. social constructivism).

In the field of teaching and learning for understanding, Richard Prawat (1999, p. 72) has stated that the abductive approach deserves a chance in the classroom. In the research described in this paper, concept mapping provided an empirical approach to investigate how students use abductive reasoning – and other modes of reasoning as well – to establish meanings useful in their learning. On the whole, little research has been devoted to how to organise a real-time, longitudinal approach that examines 'meaning-making' in normal primary school learning environments.

4 The Study

The study described in this paper was preceded by a preliminary study conducted in Helsinki (Kankkunen, 1991). This three-year longitudinal study (1989-1991) attempted to investigate how primary school students (Grades 4–6) learned to use concept mapping and whether the method generated information useful in understanding the meaningful learning process. The goal of the study was to improve teaching and meaningful learning by taking into account the classroom experience after each learning project. According to Carr and Kemmis (1986), this kind of approach qualifies as action research when it is carried out by the teacher. The strategy of triangulation was used as an alternative to validation (Fielding & Fielding, 1986), by applying a combination of methods (essays and interviewing) to support the concept mapping. The design of the study as well as its adoption of Ausubelian theory followed the ideas presented by Novak and Gowin (1984).

Although the results of the preliminary study were promising, it was deemed necessary to replicate it: it was evident that the process of establishing meaning was much more complex and versatile than described in Ausubel's theory, especially when the social classroom work was taken into account. The preliminary research therefore served as a 'pilot case study' (Yin, 1989) for the research presented here.

The four-year longitudinal study presented here was conducted in Lappeenranta, Finland (1993–1996). The study incorporated both analytical (concept mapping) and synthetic (verbal utterances) methods in the evaluation of building a learning environment for understanding.

The action research was divided into two sections:

1. The theory concentrates on concept mapping and the process of establishing meaning.
2. As a methodological experiment, the study attempts to discover in practice whether the learning environment constructed helped students to focus on the knowledge (concepts) taught in curriculum-based learning.

However, this paper concentrates on the theory-building behind concept mapping. The general objective of my research projects was to use concept mapping as a constructivistic and qualitative method for applying and elaborating meaning-making theory in the classroom.

The basic principle in the empirical study was that evaluation of learning must concentrate on measuring what students actually know, not on what they do not know. Also, the students were fully authorised evaluators of their own learning results. From this perspective, the research reported here also deals with how concept mapping aids students' self-assessment so as to encourage a positive attitude towards learning.

5 Peircean Approach to Constructing Meaning

This paper seeks to increase our comprehension of a student's conceptual learning and the world of meaning by taking into account the views of the founder of pragmatism, C. Peirce (1931–1958):

> "To learn is to acquire a habit. What makes men learn? Not merely the sight of what they are accustomed to, but perpetual new experiences which throw them into a habit of tossing aside old ideas and forming new ones." (Peirce, 1976, p. 142)

Peirce emphasises that habit alone cannot produce development: "It is catastrophe, accident, reaction which brings habit into an active condition and creates *a habit of changing habits"* (Peirce, 1976, p. 142; the italics are the writer's emphasis). Peirce reminds us that "every man exercises more or less control over himself by means of modifying his own habits" (Peirce, 1931–1958, 5.487, pp. 334–335). If a person is ready to acquire the 'habit of changing habits', it means that the person is willing to change his or her opinion. The following discussion attempts to elucidate the Peircean semiotic paradigm.

Peirce developed a semiotic paradigm that helps us understand how signs (such as words) acquire their meanings (become concepts) and also how those meanings are subsequently 'updated'. The process of acquiring meaning starts with intuition. In addition to verbal utterances, also non-verbal signs and metaphorical processes must be taken into account in 'meaning-making'. Concept mapping serves as a tool for logical and analytical learning as reproduction. The rest of the methods – the accounting interviews, group interviews, written essays and questionnaires – tend to reflect a verbal (or synthesising) attitude to learning (detailed presentation in Kankkunen, 2001, pp. 287-324). Peirce's paradigm allows investigators to take into account both semiotic and semantic aspects in learning. That is why it also helps investigators to understand the complexity in students' 'connection-making of meaning-making'. The following discussion attempts to clarify how this process works in connection with meaning-making and how Figure 1 can be of help *for a teacher* in understanding Peirce's semiotic paradigm.

In his 'method of thinking', Peirce draws an analogy between semiotics and logic which is based on the observation that all thought is represented by signs. In practice, therefore, it is impossible to separate phenomenal and logical elements from Peirce's semiotic paradigm. The Peircean semiotic paradigm is organised around three elements: 'firstness', 'secondness', and 'thirdness':

1. Firstness ('Idea'): "First is predominant in the ideas of freshness, life, freedom ... stop to think of it, and it has flown!"
2. Secondness ('Brute Actuality'): "The second category of elements of phenomena comprises the actual facts."
3. Thirdness ('Sign's Soul'): "By the third, I mean the medium or connecting bond between the absolute first and last" (Peirce, 1931–1958, 1.302–358, pp. 148–185).

The idea of 'firstness' (involving abduction or hypothesis) brings in the student's qualitative ideas and 'beliefs'. According to Peirce, "cognition arises by a process of beginning, as any other change comes to pass" (Peirce, 1931–1958, 5.263, p. 155). The idea of 'secondness' (object, referent equals induction) brings in the world of verbal and non-verbal signs that the student has already assimilated through experience, and without which effective learning and thinking cannot take place. It brings in the world of personal, chaotic experience and uses 'facts' in verifying tentative hypotheses.

In my research projects, students were encouraged to include their 'beliefs' and 'facts' in their concept maps. The idea of 'thirdness' ('updated' meaning or interpretant equals deduction) is an attempt to describe how meaning is elevated to the level of generality and how the human mind, step by step, moves through a reasoning process. The idea of 'thirdness' gives tools (meaningful concepts) for assessing the qualities that bind 'firstness' to 'secondness'. This is not to say that 'updated' meanings are perfect and immutable. On the contrary, they are pragmatic in the strict Peircean sense – useful until no longer useful. In this connection, one should also remember the importance of the 'interpretant', which is not an interpreter but a social convention or habit which indicates a social constructivist paradigm when seeking a shared meaning or concordance in some particular situation. Concept mapping can be deductive by nature, but the students' own ideas, 'beliefs' and 'facts' are essential in the making of connections.

Practically speaking, I agree with those educators who believe that it is an artificial exercise to separate the reasoning process and the learning process. However, Peirce reminds us that 'sound' reasoning is not the only tool of pragmatism. 'Bad' reasoning can start from true premises and lead to a false conclusion which can nevertheless be used successfully in real life.

Peirce emphasises that reasoning must be a conscious (deliberate, voluntary, critical, controlled) act. This is not to say that we must be aware of the whole process of the mind in reasoning – this is impossible. Peirce implies that phenomena are simply appearances. "All that we can find out by directly watching consciousness are the qualities of feeling, and those, not as they are felt, but as, after being felt, they are grouped" (Peirce, 1931–1958, 2.184, p. 108). The reasoning process starts with abduction, and any advance made in learning brings in abductive processes as a matter of course.

Abductive reasoning (intuition) involves the making of assumptions. It is the first step in understanding the phenomenon of being observed ('firstness'). From the beginning, Peircean abduction is the process of carrying meaning. However, good abduction seeks to explain the facts via hypothesis. Abduction and induction therefore work together in the construction and verification of assumptions in light of personal experience. The 'logic machine' is in a state of constant readiness to 'update' a meaning when it is no longer useful.

Abduction [Aristotle's 'retroduction'; the explanation of the concept's etymology in Peirce 1931–1958, 1.65–1.68, pp. 28–29] is closely related to the metaphoric process (Prawat, 1999). William Whewell (1860, p. 21) underlined Aristotle's contribution to understanding the growth of knowledge: "Sagacity is a hitting by guess"; and "Intuition must be the beginning of Science". The best way to learn and understand the meanings of new concepts is to master the use of metaphor (Aristotle, 1954, The Rhetoric III, Ch. 10–11; see also Ricoeur, 1991, pp. 9–43). Metaphor acts as a mediator between the three Peircean elements, 'thirdness of firstness', in trying to clarify 'secondness' (object).

Peircean 'pragmatism' concentrates explicitly on the study of meaning. As a thinking method, concept mapping shares the same concentration. Learning and thinking skills usually improve gradually, interspersed by 'leaps of intuition'. In the classroom, concept mapping can help to show how reasoning, thinking and learning are developing and changing. It is a practical tool for tracking abductive processes. Peirce says that every sign represents a process of change. In itself, therefore, the concept map is an 'updated' network of signs representing the student's thinking and learning process. These signs are the basic signs of Peircean semiotics (icon, index, symbol), which exist to clarify the meanings of concepts.

The central hypothesis of this paper is that concept mapping helps students to recognise the reasoning process and learn to control it.

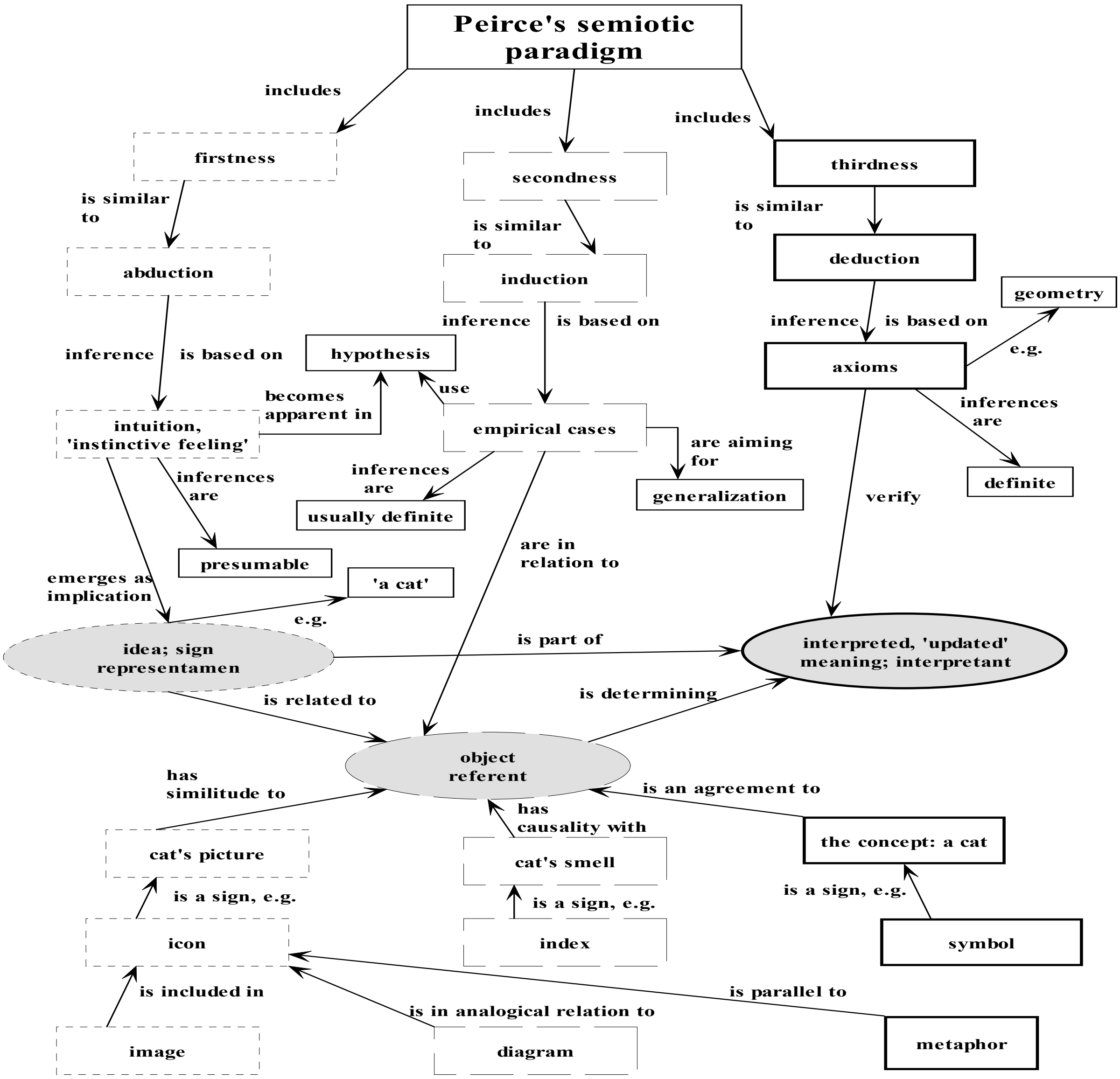

Figure 1. A concept map of the essential elements of Peircean triadism

6 Research Questions

The study sought to answer the following basic research questions:

- Does concept mapping illuminate the learning process? Does concept mapping help the teacher understand students' thinking patterns?
- Are the qualitative materials (concept maps + a combination of other methods) and quantitative criteria of the concept maps adequate for building an accurate assessment of the meaningful learning environment?
- When is the most appropriate time to start using concept mapping as a tool for meaningful learning?
- Does concept mapping help the student to comprehend the meanings of the concepts being taught?
- Is the Peircean semiotic paradigm useful in interpreting the learning process and concept mapping results?
- What do students think about concept mapping after four years of use? Do they think that it is a useful tool for learning?

7 Some Results: Attitudes Towards Concept Mapping After Four Years of Use

On the last school day of primary school, student attitudes towards concept mapping were gathered through inquiry (questionnaires) and account sessions (interviews). Such last-minute data gathering was necessary: the students knew with certainty that their opinions could not influence their academic reports, and thus their response was as honest and direct as possible. Moreover, the validity of the questionnaire in assessing students' views has the backing of Harré and Secord (1972): "Why don't we ask them?"

The classifications used in the questionnaire were word-by-word excerpts from the research diary, voiced by different students during account sessions. All the students (*N* = 23) participated in the debriefing and their views are presented in Table 1. After using concept mapping for four years, it was important to take every student's opinion into account because substantial bias can be expected in this kind of sampling (Patton, 1990). Table 2 provides a summary of their free-form opinions.

TABLE 1: Student Attitudes Towards Concept Mapping (*N* = 23)

Classifications and opinions about concept mapping	Response frequencies				
	SA	A	N	D	SD
1. Concept maps have been of help to me in my studies.	15	7	1	0	0
2. Concept maps require a lot of work.	5	7	7	2	2
3. Concept maps help me organise my learning.	15	6	1	1	0
4. Concept maps are of help when reviewing large areas of study.	14	4	4	1	0
5. The concept map clearly shows what I have learned.	8	7	4	1	0
6. While concept mapping, I must analyse what I am learning more carefully than when learning in the traditional way.	11	7	5	0	0
7. Constructing a map makes it easier to find the essential information in a text.	13	5	3	2	0
8. In the beginning, constructing a map seemed to be a lot of work but, since learning the technique, there have been no problems using them.	9	11	1	2	0
9. I would like to use workbooks instead of concept mapping.	1	1	1	6	14
10. With the help of a concept map, I can better show all of what I have learned compared to ordinary workbook exercises.	11	7	5	0	0
11. The network of links (arrows) between concepts and thoughts teaches me to get an overall view of a topic.	9	8	5	1	0
12. When I think in terms of a concept map, I remember the things I am studying better than after reading about them in an ordinary way.	10	5	5	2	1
13. Concept mapping sometimes helps me to figure out the meaning of a difficult word (e.g. ecology).	7	9	5	2	0
14. There is no sense in using concept maps as frames for essays and writings.	0	0	1	8	14
15. Concept mapping is fun.	10	7	3	2	1

SA: Strongly Agree; A: Agree; N: No Opinion; D: Disagree; SD: Strongly Disagree.

TABLE 2. Students' Free-Form Characterisations Concerning Concept Mapping After Using Concept Maps for Four Years

Favourableness of comments	Short statements
Favourable comments (n = 17)	When your thoughts are in order you can infer what the concepts mean. (n = 5) Mapping connects the concepts to their context. (n = 4) Maps help me to take into account the essential knowledge. (n = 4) Mapping polishes my thoughts and helps me to organise them. (n = 2) I do like the freedom of mapping. It gives space to my own thinking. (n = 2).
Neutral comments (n = 4)	The network of concepts does help, but sometimes you just have to guess. (n = 2) It is good that you have to think so carefully, although it is not always fun. (n = 2)
Unfavourable comments (n = 2)	Perhaps maps are of help in learning, but they require far too much work. (n = 2)

8 Discussion: Answering the Research Questions – Results and Interpretation (Kankkunen 2001)

Concept mapping as a learning tool for understanding allows the teacher and student to build a communication structure around the central concepts of the subject being taught. Students' concept maps are 'snapshots' tied to a moment in time. They show that the teacher can accurately track students' individual learning patterns and their learning progress through the continuum of the curriculum. Students stressed that concept mapping is a method that helps them to find the essential information and also helps them to organise their thoughts .

It must be stressed that assessment of the concept maps should take place in the normal classroom context. Concept mapping is qualitative by nature, and assessment focuses on the structure as a whole: What does a student's learning 'look like'? In practice, this will be sufficient for most teachers in the classroom. When a more detailed assessment is required, a combination of other methods including quantitative assessment can be used.

Both qualitative and quantitative evaluations are needed to build an accurate assessment of meaningful learning environments. The criteria used in this study gave a detailed picture of how students developed in their concept mapping tasks. The results show that the 'better' concept maps included many 'central concepts' and 'valid propositions'. These are the essential quantitative criteria in assessing the quality of 'the connection-making of meaning-making'. These 'better' concept maps work like 'close-up snapshots', cutting out extraneous background information to focus on the central concept(s) of the topic.

The results show that the transition to conceptual learning, marked initially by a deeper understanding of 'connection-making', usually occurs in the fifth grade at the age of 10 or 11. However, the individual differences are huge. The transition can be seen particularly clearly in the greater number of 'valid propositions' and in the quality of 'central concepts' through the comprehensive assessment of concept maps and accounts. This finding is similar to the results of the preliminary study.

In the final account sessions, 22 of 23 students described Novak's 'less is more' philosophy using a variety of their own words. In assessing themselves, they concentrated on key concepts which they understood and left out the concepts they did not understand. The evidence in the accounts and questionnaire shows that concept mapping helped the students find the essential knowledge in their learning.

When the student's learning process is put through Peirce's semiotic paradigm applied to concept mapping, the teacher can reach a more complete understanding of how concepts are taught and learned. In interpreting the concept maps, Peirce's semiotic paradigm was instrumental in illuminating the 'connection-making of meaning-making'. The results show many parallels between concept mapping and the Peircean semiotic paradigm, including how abductive reasoning works as a carrier of meaning. Moreover, concept mapping serves as an aid to abductive reasoning (a tool to help students to acquire 'the habit of changing habits') because it allows for continuous concept updating and gives the student access to the verbal and non-verbal signs needed to build new and meaningful connections.

Concept mapping as a method and discipline helps students to gain control over their reasoning by allowing them to visualise it. For the teacher, applying Peirce's semiotic paradigm (Figure 1) in interpreting concept maps helps in following the student's conceptual development. It provides a detailed model of how the reasoning faculties develop, step by step, in relation to the connecting-making (meaning-making) process. The results of my study show that the students' development in meaning-making clearly lay within the framework of Peirce's semiotic paradigm. Concept mapping clearly promoted the conscious use and refinement of reasoning during the learning process.

After having used the method for four years, most of the students found concept mapping to be demanding (Table I) and very useful for their studies: 15 of 23 'strongly agreed' that concept maps had been helpful.

8.1 Implications

Conceptual learning is the intermediate goal of the learning process, which cannot be reached unless the student consciously understands how the concepts being taught are connected. The results of this study support Vigotsky's assumption that learning precedes development, and show that concept mapping is a powerful 'advance organiser' (Ausubel) on the road to conceptual learning. Concept mapping allows students to apply more of their intellectual abilities in making reasoned assumptions by helping them to identify and visualise the complexity of the thinking process.

Concept mapping provides a means for teachers to study their own professional development within the 'less is more' philosophy. Over the long-term, the teacher can follow students' development at suitable intervals, time allowing. Concept mapping is also flexible enough to be used in conjunction with other tools that promote learning: we have developed with my colleague, BA Jyrki Ylärakkola, a concept mapping multimedia software (Konsepti) in order to promote the network learning (Ylärakkola & Kankkunen 2002).

During this study, students were attracted to concept mapping in part because the method does not (or should not) enforce a 'right and wrong' learning dichotomy. Mistakes are allowed because they are essential to the learning process – too great a reliance on quantitative testing and scoring can inhibit the 'liberality' of concept mapping. The moments in learning when concepts are 'updated' can be caught by the free-style concept mapping 'snapshots' and the free-form accounts ('photograph explanations'). This process works naturally within the Peircean semiotic paradigm and the abductive reasoning dimension: the natural rhythm of learning is rarely linear, being more a matter of 'one step forward and two steps back'.

The empirical foundation of Peirce's semiotic paradigm makes it a suitable theoretical framework for use with concept mapping in clarifying concepts and tracing meaning-making and connection-making in learning. Students are encouraged to take past experience into account in 'updating' to more precise meanings for their concepts, just as Peirce described. His social constructivism emphasises the intuitive aspects of the meaning-making process, in practical opposition to the followers of 'radical constructivism' often cited by Novak.

How exactly can Peircean theory help the teacher to interpret concept maps and other data? The answer depends a lot on the evaluator. Gary Shank (1987, p. 289) has pointed out that "using abduction and semiotics in educational research is like learning to read another language. You do not have to give up your native tongue to read another language, but it will never look the same again. Likewise, when you adopt abductive strategies in research, you don't have to abandon empirical testing, but empirical testing will also never look the same again." This is very true of how Peircean theory can be applied to interpret empirical concept mapping 'snapshots', and of how it can help the teacher to 'read' students' thoughts more accurately than before.

Moreover, the accounting method of interviewing and the group discussions give students 'another chance' to clarify their thoughts verbally. When focusing on the semiotic side of meaning-making in the classroom, Jay Lemke (e.g. 1987) has emphasised the need to look beyond the immediate communication context to the myriad influences of social systems. The logically organised structure of Peircean theory is very useful in organising and understanding the great number and complexity of social semiotic interpretations that exist in the classroom. Learning involves the interaction of a universe of signs, objects, and interpretants while our concepts move closer and closer to their 'final' interpretants. Nathan Houser (1987, p. 273) talked about the Peircean semiotic theory of learning and invited investigators to develop it further. In this study, Peircean theory could be brought to bear in clarifying the interpretations of concept maps throughout the duration of the action research – at any point. Without this total applicability, would it even be possible for a teacher to focus systematically and consciously on his or her teaching of the 'connection-making of meaning-making'?

The signs in the concept mapping 'snapshots' created during this study are evidence of the method's suitability for promoting 'good reasoning' in the learning environment. In Peircean logic, the reasoning process moves from 'true premises' to 'valid conclusions'. In concept mapping 'snapshots', this is seen in the movement from 'valid propositions' to useful 'updated meanings'. In this study, the 'most advanced' group and the 'least advanced' group showed development in logical thinking. This is seen in the quality of their concept maps and, quantitatively speaking, a number of misconceptions and unconnected concepts no longer appeared in the later examples. In Peircean terms, their connection-making abilities were seen to improve across the board.

The question remains: What part of this improvement is attributable to concept mapping in isolation, and what part is attributable to all the other dynamics of the learning environment constructed during the study? A Peircean pragmatist would answer that, because the arrangement produced 'good' results, concept mapping was a pragmatic tool that clearly promoted learning for understanding.

Another question then arises: Were the results 'good'? To answer that question, the voices of the students themselves should be listened to because they are, perhaps, the best evaluators of their own learning. The students in this study had used a wide variety of different learning methods in their schooling, and found concept mapping to be very useful in learning for understanding. To build better meaningful learning environments, teachers should be more interested in students' attitudes towards the practicality of school learning – whether it makes sense to them. Methods such as concept mapping can help to encourage useful discourse on this subject.

Although A.N. Whitehead (1929) was perhaps the first, many scholars have confronted the paradox that school learning often has little to give to the student in 'real life'. School should be a place where diverse areas of knowledge are organised in meaningful forms, regardless of where the knowledge comes from. For students, school can be a place of knowledge integration – where they can display all the knowledge and information they possess, whatever the source. Concept mapping provides a means for doing just that in a naturally-structured way.

Teachers seeking to help learners to understand more cannot be too selective in the natural learning context. Many manifestations of thinking should be taken into account, to make learning an overt phenomenon in which both individual and social learning occurs. This requires the teacher as practitioner continuously to search for methods – and new combinations of methods – that give the student 'room to think'. They must adapt and elaborate theories so as to monitor meaningful learning more accurately. In this sense, educational research can 'step inside' the classroom more, to study what is happening over the long-term in the natural learning environment. The Peircean semiotic paradigm provides a good basis for such work in future concept mapping studies. Concept mapping and Peircean theory can meet in the classroom for the benefit of students and their meaningful learning.

Learning rarely becomes learning for understanding with mere repetition, although repetition certainly has its place. Throughout his writings, Peirce warns us of the dangers of routine and repetition, and emphasises the importance of 'something stopping us doing the usual' – that is, we should search for something that makes us acquire 'a habit of changing habits'. In visualising the knowledge structure as an explicit tool, concept mapping can be a method that encourages the student to acquire 'a habit of changing habits'.

Learning how to learn is to some degree an innate talent. However, it is also a skill that can be nurtured and developed. In promoting this goal, a school succeeds when students feel that school learning makes sense. This positive attitude towards learning will grow if the student's voice is listened to. Usually, this motivates them to take responsibility for their own learning. The student self-assessments in this study show that students are capable of evaluating themselves and their abilities in a mature way given the chance. Concept mapping allowed them to evaluate their own progress in parallel with normal quantitative evaluations, without being put in the spotlight in the classroom. Students can be allowed to decide the pace of this process; once they have bought into it, their self-motivation can spur their progress in learning.

After using concept mapping for four years, the students in my study were very positive about concept mapping and had become skilled practitioners of the method. As their learning progresses through Vigotsky's stage of conceptual learning and into adulthood, the discipline of honest self-assessment nurtured by concept mapping can become a 'good habit' that can sustain a lifelong desire for learning.

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SYNCHRONOUS COLLABORATIVE CONCEPT MAPPING VIA ICT: LEARNING EFFECTIVNESS AND PERSONAL AND INTERPERSONAL AWARENESS

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Abstract. This study investigated both learning effectiveness and personal and interpersonal awareness in synchronous collaborative problem-solving concept mapping (CM) via ICT with two computer communication channels. Sixty students in 30 groups drew their shared concept maps in three conditions of the experiment, face-to-face (FtF), ICT with text, and ICT with audio and text connection. In interpersonal awareness, participants in the audio/text group had lower performance in attention and total score in comparison with FtF group and lower performance in reaction with both text and FtF groups. In learning effectiveness, there were no significant differences amongst the groups, but in learning effectiveness at the level of the group as a whole the performance of the text group was better than both FtF and audio/text groups. The results show that CM in collaborative learning situation via ICT can be used as effective as FtF and more research is needed to show the reason of lower performance of the text/audio group.

1 Introduction

Over recent decades, learning and teaching have not been immune from the general trend towards use of information and communications technology (ICT). In fact, education has traditionally accepted some forms of new technology easily, such as the interactive white board. But in spite of the widespread usage of technology in education, the role of technology has not been considered as central to learning and teaching processes until recently. This is because technology was not able to support some critical aspects of educational activities, such as collaborative learning and face-to-face interaction, and could not replace other facilities within the classroom. With the emergence of ICT, consideration has been given more to use of this technology to confront with these challenges both in relation to the content and methods of learning and teaching. With the opportunities afforded by ICT, the possibility of addressing these requirements on educational system is close to being realised. Obviously in this area, one of the challenges is finding ways and methods that learning effectiveness can be promoted in leaning and teaching via ICT. In this regard, one solution is the application of mind tools, like CM, in learning and teaching via ICT. But in view of the differences between traditional and electronic methods, more research is needed to explore the optimal facilities and methods for using the mind tools in learning. This study gives consideration to use of CM as one of the most effective mind tools, and collaborative learning as one of the most widespread learning strategies, in learning via ICT.

2 Mind Tools and Concept Mapping

Mind tools are one of the effective applications of technology in education. They have derived from learning and educational theories to promote learning and teaching. Jonassen describes mind tools, or cognitive learning tools, as “computer-based tools that facilitate generative process of information by learners” (1992, P. 3) and “facilitate critical thinking and higher-order learning” (1999, P.152). Mind tools include a wide range of technologies from databases, spreadsheets, and semantic networks to multimedia construction tools and expert systems. Research results have shown that the use of mind tools can promote the process of learning. Therefore, the application of mind tools can be a desirable addition to many educational activities requiring deep engagement with learning materials. One of the most useful mind tools, with a strong theoretical and research background, is CM which belongs to a category of computer tools that were designed specially for learning (Jonassen, 1992).

Novak began to study and develop the CM technique in the 1960s. Although researchers have presented many definitions for CM, most of them are common in their application of a few key words: *node* (concept, point, vertices), *link* (line, arc), *proposition*, and *graphical* or *visual representation*. Reader and Hammond (1994) suggested a simple definition for concept map as " a graphical representation of domain material generated by the learner in which nodes are used to represent domain key concepts, and links between them denote the relationship between these concepts" (P. 52). According to Anderson (2000), a proposition is the smallest linguistic unit that carries meaning. The effectiveness of CM has been shown by many research studies in various fields and so researchers and educators in a wide range of sciences have used it (e.g. Stoddart, Abrams, Gasper, & Canaday, 2000). Generally, ways that CM can be effective may be summarised as below: a way of representing knowledge and measuring it, an activity that promotes learning of certain sorts of knowledge, and a tool for measuring changes in knowledge.

2.1 Concept Mapping with Technology

Four different steps can be recognised in technology use in CM. In the first step, CM was carried out using paper and pencil, requiring a lot of time and effort both from students, for creating and revising, and from teachers, for evaluating the CMs. This emphasis on process may have resulted in less attention being given to the knowledge itself (Chang, Sung, & Chen, 2001). The second step began with expansion of personal computers. Using software developed for creating CMs, students and teachers could construct, modify, maintain, and analyse CMs more easily. This step was developed further with the advancement of multimedia, allowing the use of sounds, video and pictures in concept mapping. The third step extended the use of CM within hypertext and hypermedia, with an emphasis on its role in learning and teaching (Hammond, 1993). For example, Reader (1994) worked on CM tools with hypertext and suggested that constrained knowledge structuring tools may provide a useful for aiding the process of learning. Finally, the development of the Web resulted in developments and research into the use of CM within web-based environments (e.g., Tsai, Lin, & Yuan, 2001). The current focus of research is on the web-based CM with synchronous and asynchronous communicative facilities (e.g., Cañas et al., 2001). Collaborative CM has therefore become feasible even when participants are distributed. The trend towards web-based CM systems provides opportunities for the application of concept mapping within electronic learning environments, like VLEs.

3 Collaborative Concept Mapping

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 group maps. It supports discussion about concepts between members of a group.

Computers and ICT have been used to support collaborative CM since the mid-1990s (e.g. Cañas et al., 2001) and some moves to create web-based tools with collaborative facilities have taken place (e.g., Luckie, Batzli, & Ebert-May, 2002). Gaines and Shaw (1995) carried out one of the first attempts to use CM for collaboration on the Web. However, their work focused more on the technical aspects of the collaborative CM on the web and was not concerned with the learning and teaching situation. Cañas et al., (1995) used a "knowledge soup" as a collaborative software system. This was a store of students' concepts and links they had used for their concept map. All users could see them without seeing the whole of other students' CMs. The research showed with collaborative effort students could elaborate, refine, and improve their own knowledge structures. The authors believed more research was needed to improve the methods for using collaborative concept mapping as a tool for representing knowledge (Cañas et al., 2001).

The application of CM as a collaborative tool has been used both in educational and business setting and both in FtF and at distance learning, either synchronous or asynchronous (Cañas et al., 2004). Although some research suggest that collaborative CM is an effective tool that can lead to effective discussions concerning concepts and thus enhance meaningful learning (e.g., Fischer, Bruhn, Grasel, & Mandl, 2002), others have shown that collaborative CM is not effective (e.g., Chung, O'Neil, & Herl, 1999). It causes more research to tackle this incompatibility and more focus on the process of collaboration in collaborative CM. 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 the complex co-operative tasks led to better performance in a group. Boxtel, Linden, and Kanselaar (2000) studied the influence of task characteristics on the elaboration of conceptual knowledge in social interaction. They compared CM with a poster task and investigated the effect of individual preparation in learning. They found CM had a significant effect on discussion about concepts, collaboratively elaborated conflicts and reasoning, but no higher individual learning outcomes. Stoyanova and Kommers (2001) 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.

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. This study is the first of a set that investigates some of the issues in this area. It was an exploratory one involving the implementations of a learning system that makes use of synchronous web-based CM to encourage higher-level thinking using collaborative learning structures via ICT. Two specific issues of this study relate to the communication channels used and to the comparison of learning effectiveness of collaborative CM either FtF or via ICT. Thus, two questions are addressed in this study: (1) is collaborative synchronous, web-based, CM as effective as collaborative CM using FtF? (2) What CMC channels are needed to improve collaboration in synchronous CM via ICT?

4 Method

4.1 Design and Participants

This study used a between-subject design. The between-group variable was the kind of computer-mediated communication channels in collaborative web-based problem solving CM task with three levels: online with written chat (text) versus online with audio/text connection versus face-to-face (FtF).

Thirty pairs of participants from York University (12 males and 48 females; age 17 to 23 with mean of 19.2 years) volunteered to take part in the experiment. Twenty participants, ten pairs, served in each condition. There were no significant differences among the conditions regarding the participants' age, average working with computer per day, computer and CM knowledge and experience, working with yahoo messenger, and working in collaborative learning situations ($P < .05$). 47 participants were native (British). The gender and nationality composition of participants in collaborative conditions was controlled, with nearly the same numbers of each possible gender pairing and nationality in each condition. The degree of friendship between participants was controlled: each participant had to bring a friend as a partner.

4.2 Pilot Study

A pilot study was conducted to choose a suitable collaborative problem-solving CM task, and to evaluate the experimental instructions and procedure and use of the software. For choosing a suitable task, a group of postgraduate students suggested some possible topics by brainstorming and the two most suitable tasks were chosen for the pilot study. Eighteen participants, two pair groups in each condition (FtF and ICT) and each task (termed *planning a university campus* and *graffiti*), answered to two questionnaires. In the first questionnaire, they assessed the tasks on collaborative criteria, including motivating, interesting, CM usability, concept diversity, collaboration, and controversy. In the second questionnaire, participants assessed the instructions and the software of the experiments. The results showed participants believed the university campus task had better capability for using in a collaborative problem-solving CM situation. In addition, on the basis of the results, some parts of the research protocol and the instructions were amended.

4.3 Material

IHMC CmapTools beta version 3.0 (dsp) was used for CM. This software allows users to collaborate on making a CM. With the collaborative part of the software, users can immediately see changes made by their partner on a shared CM and communicate via a chat room. For CMC channels, Yahoo Messenger version 5.0 was used in the collaborative groups. Experimental sessions took place in controlled experimental rooms equipped for remote communication. Each room had a PC with all necessary equipment. A set of written instructions were provided. Participants completed four types of questionnaires. The first, completed before the experiment; measured their previous abilities, experiences, and knowledge of computer, CM and collaborative learning. The other questionnaires were filled out after the collaboration session by participants who served in collaborative groups. The technology questionnaire measured the participants' evaluation of the technology, CmapTools and Yahoo Messenger software. The third questionnaire assessed participants' awareness in communication, based on a questionnaire developed by Monk and Watts (1998), and with two sections, interpersonal and personal awareness. In the original questionnaire, the first section consisted of 12 items that asked participants how aware they were of their partner with six measures (presence, reactions, attention, contribution, understanding, and addressing). As the experimental groups were dyads, two questions regarding addressing were omitted. The second section consisted of ten items related to personal awareness (engagement, involvement, role, attention, and interest). The questions regarding the role were omitted because were not related to the task. Each measure of the questionnaire had one positive and one negative item. There was also an open-ended question in which participants could write any comments they had about the task. In fourth questionnaire participants reported their assessment about who led the collaborative session in terms of the constructing the map and contributing knowledge and ideas for constructing the map. In all questionnaires, the participants gave their answers on a 100mm analogue Likert-type scale.

4.4 Procedure

Participants initially filled out the personal detail questionnaire, were provided with written instructions and a short training session place. In this session, the experimenter drew a sample concept map with Cmap and answered any questions related to the experiment and the software. Then participants had 15 minutes to draw an individual concept map. The task was a scenario about the planning of a new university campus. After this step, participants were divided randomly into the three conditions of the experiment. In condition one, participants used CmapTools software to make a CM with FtF collaboration. They worked together on the previous task. In the second and third conditions, participants were given the same task but in separate rooms. For collaboration, they used the online collaborative part of CmapTools but with different CMC channels. In the second condition, participants used the written chat room of Yahoo Messenger whilst those in the third used both the written and audio connection of Yahoo Messenger. Participants, in all conditions, had a maximum of 40 minutes to draw a shared CM but could finish earlier if they felt their map was complete. At the end of this session, participants filled out the technology and awareness questionnaires.

4.5 Scoring System of Concept Maps

Whilst CM technique has been accepted in many fields, assessing a CM has remained a controversial issue. A proposed taxonomy for analysis levels of learning effectiveness in collaborative CM is developed in Khamesan & Hammond, 2004. On the basis of Stonayova's and Kommers's initial work (2002), learning effectiveness is divided to three levels, the level of individual learning, the level of the group as a whole, and the level of interaction between individual and group. For each level, a number of sublevels are proposed that can be used as a basis for analysis of learning effectiveness in collaborative CM and other collaborative task. Table 1 presents definitions of levels and their sublevels. The taxonomy includes provision for a post-test session, not included in the current study.

4.6 Reliability of Scoring System and Questionnaires

The reliability of the awareness questionnaires were calculated using Chronbach's Alpha. The questionnaires show high reliability, with r =.87 for interpersonal awareness, r =.67 for personal awareness and r = .81 for the whole of questionnaire. The reliability of the scoring system was calculated by inter-rater reliability. Three raters marked 30% of CMs (48 CMs). The correlation among the raters' scores were high on nearly all measures (between r =.52 for and r= 1), indicating good reliability of the scoring system.

5 Results

A brief summary of the result of the experiment is presented in three sections: using technology, CMC channels, and learning effectiveness. The mean for each scale was analysed, with a score between 0 and 100, where a high score on the question represents a high level of agreement with the question.

1. Learning effectiveness at the individual level:

1.1 ***Individual Achievement:*** Total number of concepts in post-test. It includes sublevels of enrichment and retention. (*)

1.2 ***Enrichment:*** Difference between post-test and pre-test. It includes: (**)

1.2.1 **Knowledge Acquisition**: New concepts in post-test. It includes concepts transferred from the group CM and new individual concepts.

1.2.1.1 ***Individual Creativity****:* New concepts that were neither in pre-test nor in group CM.

1.3 ***Retention****:* Concepts are transferred from pre-test to post-test.

1.4 ***Structure & Configuration****:* Distribution of concepts in different levels in relation to central concept. (**)

2. Learning effectiveness at the level of the group, as a whole: *2.1* ***Group Achievement****:* Total number of concepts in group CM. (*) *2.2* ***Structure & Configuration****:* Distribution of concepts in different levels in relation to central concept in group CM. (**) *2.3* ***Group Creativity****:* New ideas and concepts, in group CM, that are not in pre-tests and are created only in collaboration session.
3. Learning effectiveness as an interaction between individual and group achievement 3.1 ***Individual-to-Group Transfer****:* Concepts are transferred from pre-test to group CM. *3.2* ***Group-to-Individual Transfer*** *(Retention in group level):* Concepts are transferred from group CM to post-test. (*) 3.3 ***Individual-to-Individual Transfer****:* Concepts are transferred from one of peer's pre-test to his or her partner's post-test. (***) 3.4 ***Rejection at Group Level****:* Concepts of pre-test that are not transferred to group CM. (***) 3.5 ***Rejection at Individual Level****:* Concepts of group CM that are not transferred to individual post-test. (***) 3.6 ***Overlapping****:* Overlapping of individual CMs, both between individual pre-tests and individual post-tests. (***)
Note: Asterisks at the end of each sublevels show type of amendment from Stoyanova and Kommers's work (2002): (*) indicates only change of name, (**) indicates change of definition or re-categorisation, and (***) indicates new sublevels.

Table 1: Levels of learning effectiveness analysis

5.1 Using Technology

The means, standard deviations, and the results of ANOVA of participants' assessment of the technology, Cmap and Yahoo Messenger, used in the experiment have been presented in table 2. The results show participants in both FtF and ICT groups agreed on the positive performance of CmapTools both in individual and in collaborative concept mapping and used the software without any major problem. Participants in ICT groups assessed use of Yahoo Messenger positively. There were no significant differences between groups regarding agreement on technology used in the experiment (P>.05).

Questions	**Conditions** FtF	Text	Text/Audio	F	df	P
1) Perfect performance of Cmap in individual concept mapping	71(20)	81(12)	80(12)	2.68	38	.08
2) Perfect performance of Cmap in collaborative concept mapping	78(13)	74(16)	67(23)	2.18	38	.12
3) Working without problem with Cmap in collaborative concept mapping	70(25)	75(14)	7423)	.36	38	.73
4) Perfect performance of Yahoo Messenger		87(10)	86(13)			
5) Working without problem with Yahoo Messenger		84(15)	84(20)			

Table 2: Means (and standard deviations) of participants' agreement on technology used for concept mapping and collaboration

5.2 Awareness in Collaboration

The awareness questionnaire had two sections, *interpersonal awareness* (or awareness of others), with five measures (attention, presence, reaction, understanding, and contribution), and *personal awareness* (awareness of self), measuring impressions of enjoyment, involvement, attention, and interest. The results of the awareness questionnaire are presented in figure 1 (personal) and figure 2 (interpersonal).

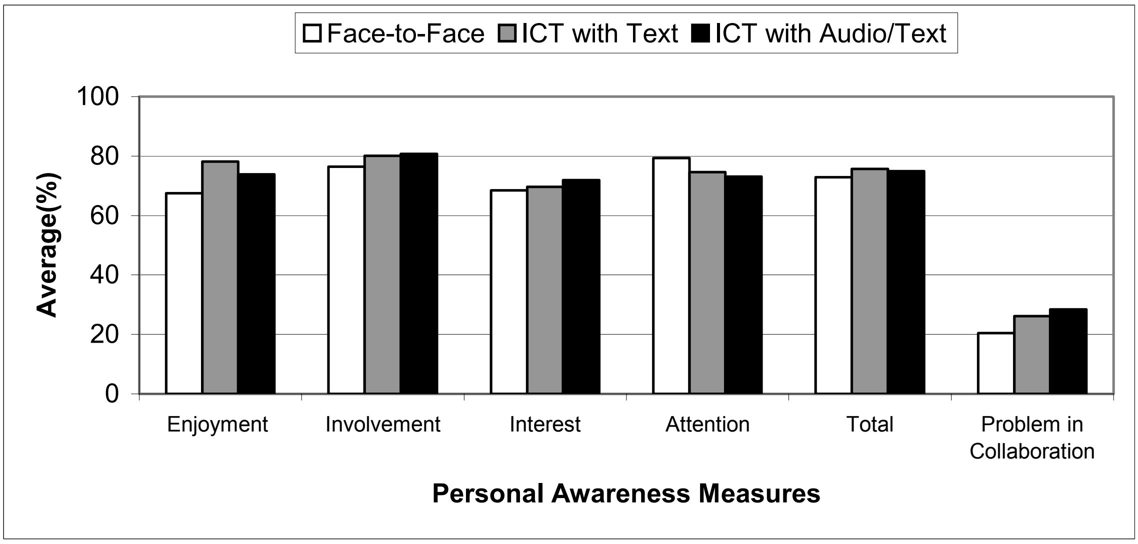

Figure 1: Personal awareness measures

For personal awareness, there were no significant differences between mean scores for each condition. The participants in ICT groups had slightly higher personal awareness for three of the four measures. The final group on the graph (*problems in collaboration*) presents results from a question regarding the problems that the participants had in collaboration. The differences were not significant although the FtF group reported slightly fewer problems than the two ICT groups.

For interpersonal awareness, analyses of variance revealed statistically significant differences amongst the groups in measures of attention (F= 6.81, df=59, P=.002) and reaction (F= 9.25, df= 2,59, P.000), and in the total interpersonal awareness score (F= 6.32, df= 2.59, P=.004). Tukey HSD tests showed that the FtF group had significantly higher scores than the audio/text group in attention and total interpersonal awareness (P> .01). For the reaction measure, the audio/text scores are significantly lower than the scores for both the other two groups (*vs* FtF, P=.000; *vs* text, P= .034).

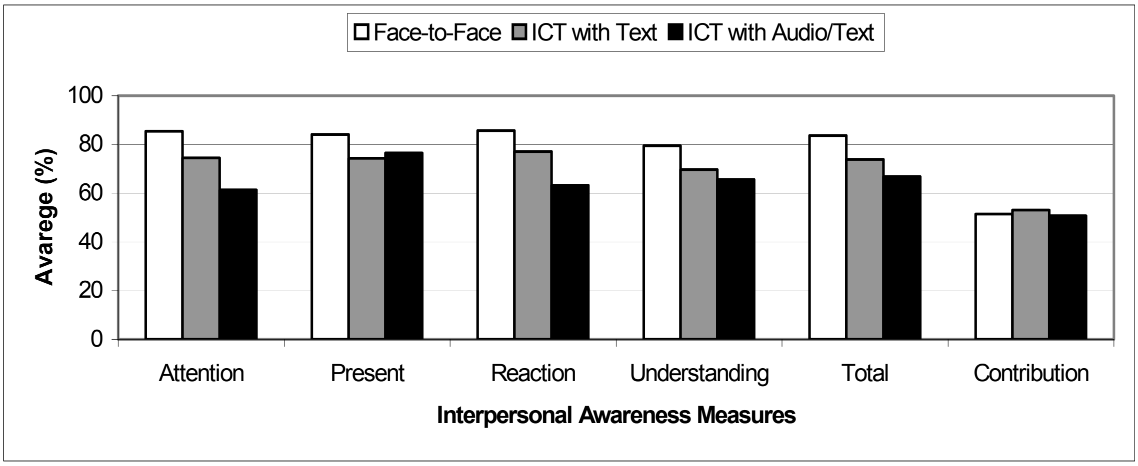

Figure 2: Interpersonal awareness measures

5.3 Learning Effectiveness

Each participant constructed an individual CM in the pre-test phase and a shared concept map with his or her partner in the collaborative session, with a total of 90 CMs constructed. The scoring of the individual CMs show that there were no significant differences among groups in any of measures relating to base level, structure and configuration of CMs (P>.05).

Learning effectiveness was measured in two ways. The first was in terms of the shared CMs using three measures: *group achievement* (number of concepts), *structure and configuration* (reflecting map structure) and *group creativity* (new concepts not present in either individual CM). The second was in terms of the interaction between shared and individual CMs, with two measures of *transfer* (number of concepts in shared CMs also present in the individual CMs) and *rejection* (number of concepts in individual CMs not included in the shared CM).

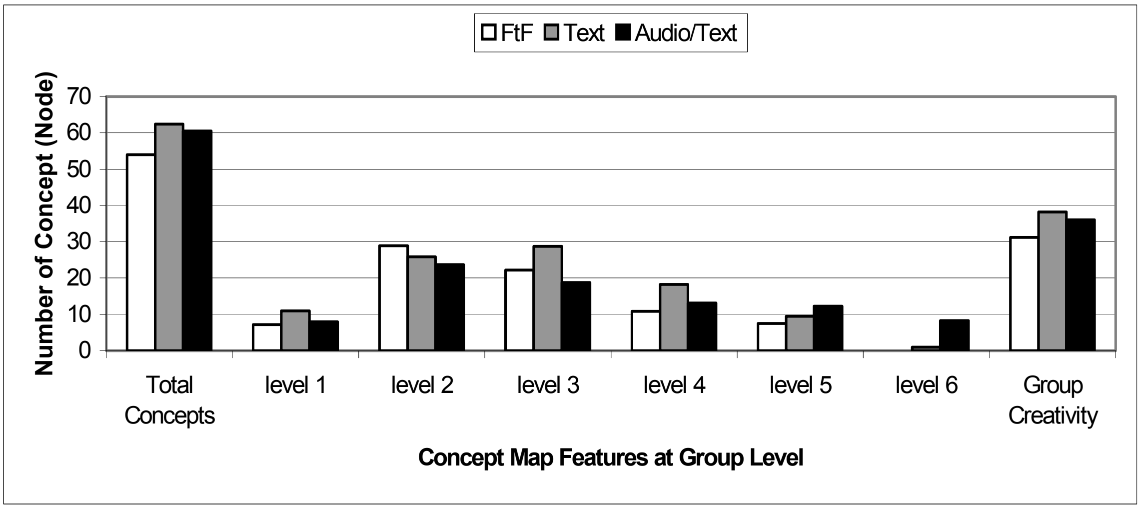

Figure 3: Learning effectiveness at the group level

The results of learning effectiveness at the group level are presented figure 3 which show total concepts and concepts at each hierarchical level. Analysis of variance showed no significant differences between the groups, although numerically the text group generated more concepts than the other two groups. The results of learning effectiveness at the interaction level are presented table 4. There were no significant differences between the groups in transfer and rejection rates.

Measures	Conditions		
	FtF	Text	Text/Audio
Individual to group transfer	26(9)	21(11)	24(7)
Rejection at the group level	26(20)	22(13)	22(8)

Table 4: Means (and standard deviations) of learning effectiveness measures at the level of interaction between individual and group

6 Summary

The result shows that computer-based concept mapping can be use in collaborative learning with remote communication as effectively as with face-to-face communication, although more research is needed to clarify issues how performance is mediated by different CMC modes. Participants using audio/text communication showed lower levels of interpersonal awareness (on measure of attention and total score) in comparison with the FtF group, and lower performance in the reaction measure compared to both other groups. This effect was unexpected insofar as the text only group would be expected to have the lowest communication bandwidth. The finding might be in part caused by the higher loading of the computers in audio/text conditions causing some degradation of communication speed: this possibility is under further investigation. However the finding does suggest that where network performance is not of high quality, using typed communication for collaborative CM might be just as effective as audio communication.

7 Acknowledgements

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PROMOTING DEEP APPROACHES TO LEARNING IN SCIENCE WITH SEQUENTIAL ASSESSMENTS

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Abstract. Scientific literacy requires deep learning of science concepts. A suite of sequentially dependent assessments, which includes online chapter quizzes, concept mapping, and essay exams, was employed to promote deep learning. These assessments were evaluated in a pilot study that included survey instruments for each assessment type and for the overall course as well as open-ended questions for each assessment. Analysis of the surveys and comments resulted in several hypotheses to be tested with subsequently collected data. Hypotheses from this pilot study include: 1) sequentially dependent assessments promote deep learning in science 2) adequate support and acceptance of concept mapping and essay exams affect student approaches to learning 3) concept mapping is effective for construction of knowledge and for developing the ability to communicate that knowledge 4) assessments that promote surface learning are a prerequisite for concept construction and communication.

1 Introduction

The problem of scientific literacy has been the subject of literally hundreds of reports over many decades (e.g., Educational Policies Commission, 1966). Science literacy is not simply measured by knowledge of science terms, nor is it necessary for all citizens to be able to perform as competent scientists (Shamos, 1995). Rather, what all citizens need is an understanding of our knowledge about nature, an ability to use the concepts of science as they show up in everyday life, and an awareness and appreciation of the process of science. Over the years, we have made progress in transforming the way we teach science to improve science literacy (e.g., Lawson, 1988). Regardless of our progress, much still remains to be done. Our students may have improved their achievement on objective tests, but, when asked to explain fundamental concepts, they fail. When asked to apply concepts in new situations, they fail. And when asked to make connections between related but separately discussed concepts, they fail. What seems to be happening is that students are failing to develop deep understanding of the concepts they are learning.

Recently, the National Research Council published a book linking research on *How People Learn* to classroom practice (Bradsford et al. 2000). Key findings of this synthesis are that 1) student preconceptions affect learning, 2) deep learning requires students to develop a conceptual framework for knowledge about a subject, and 3) a metacognitive approach to learning can help students achieve their learning goals. This excellent review concludes with implications for teaching to implement their key findings. Comparison of our practices in science education to these recommendations suggests that inquiry instruction provides an excellent structure for dealing with student preconceptions. However, science education does less well in helping students structure their conceptual knowledge and in promoting student monitoring of their progress toward learning goals. Much of what happens in the science classroom seems to guide students toward a surface approach to learning (Moore 1996, Novak, 2003). In fact, Halpern and Hakel (2002) assert that “it would be difficult to design an educational model that is more at odds with current research on human cognition than the one used in most colleges and universities.”

2 Alternative Assessment to Promote Deep Conceptual Learning

How can we motivate our students to achieve deep learning? Among other factors, assessment can have a significant impact on learning. Students seem to adapt their learning approach to the assessment expectations built into our courses. Thus, surface level assessment promotes surface level learning. In course design, our objectives must be embedded in assessment tasks. If for example course objectives focus on the big questions of biology, assessments must also focus on the big questions of biology. Our students should achieve understanding of those concepts and be able to communicate that understanding.

Three years ago, I undertook a redesign of my introductory biology course that primarily focused on matching my assessments to my course objectives. My resulting course design can be described in a concept map based on the sequentially dependent components of surface learning and concept construction to promote

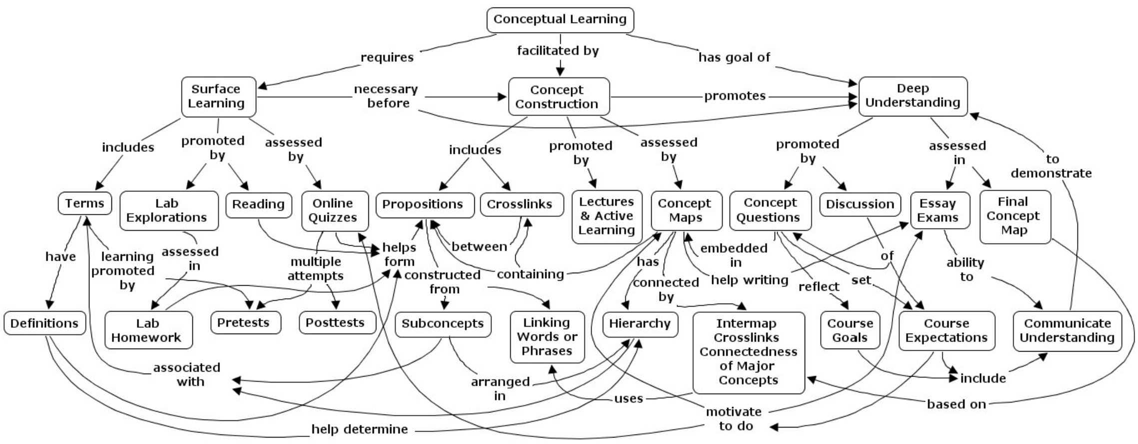

Figure 1. Concept map of sequentially dependent components of learning with assessments to promote deep conceptual learning.

deep understanding (Figure 1). Sequential assessments including online chapter quizzes, concept mapping, and essay exams are central to my educational model for promoting deep conceptual learning.

My assessment suite begins with online quizzes delivered in an online course management package. They were intended to reinforce reading and ensure surface learning. Each quiz comprised 20-40 questions for each of 9 chapters covered in the course. The focus was mastery of the vocabulary of the chapters. Students were given a list of terms for each chapter that they were expected to define and learn. I allowed students to have multiple attempts at taking these quizzes and gave them the highest score they received.

Concept mapping was employed to promote connections among the facts and theories associated with each biological concept (Novak, 2003). Concept mapping is a visual tool for construction of knowledge that can also be employed as an assessment tool. Students were required to use the term lists as the basis for a concept map of each chapter. In addition, I devised a final exam consisting solely of a course-level concept map wherein points were awarded only for valid crosslinks between the branches of a map that consisted roughly of the ten major concepts studied over the entire semester. Concept mapping can be especially valuable because of its ability to depict and promote learning of interrelations of concepts. I believe these crosslinks are the beginnings of deep understanding.

Finally, I employed essay exams as a final assessment of my student's deep understanding of the concepts covered in the course. I believe that writing about a concept is best test of deep understanding. Therefore, I wrote a set of 9-12 broad questions for each of my midterm essay exams, which were given to the students in advance. These were guided essay questions in that they prompted students to cover specific areas in their essays. For each of my three midterm exams, students were given four of the questions from which they could choose three on which to write their essays in class.

3 Student Evaluation of Assessments: Methods

To evaluate my alternative assessments, surveys were administered anonymously with our course management software. Survey questions included Likert-scaled items on 4 areas: overall course (26 questions), online quizzes (17), concept mapping (17), and essay exams (23). In addition, students were presented with an opportunity for open-ended comment on each assessment type. The survey was administered during the last week of classes.

Survey data were analyzed using principle components analysis of each survey area separately with varimax rotation to reduce the dimensionality of the data. Thus, a few new composite variables were produced for each assessment type, which retained most of the variation present in the original variables. These new variables can be interpreted by their correlations with the original questions and are independent variables with mean = 0 and variance = 1. Student comments were analyzed by scanning the responses to identify response categories. Then, all comments were distributed into one or more of the categories. Representative comments were excerpted, and the number of similar comments received was tallied. These qualitative data were used to substantiate the components of variation extracted from the survey data and the interrelations among student evaluations of the assessments and the overall course. Finally, simple correlations among factors (i.e., principle components) from each of the survey instruments (online quizzes, concept mapping, essay exams and the overall course) were used to explore student perspectives of how assessments relate to aspects of the overall course and to each other. Data analyzed in this pilot study were from a single class during the fall of 2001. At high point, this class included 30 students of which 23 students completed the class and contributed to the data for this pilot study.

4 Student Evaluation of Assessments: Results of a Pilot Study

4.1 Online Quiz Components of Variation

Student comments on the online quizzes overwhelmingly support the idea that this assessment helped them learn. Fifty percent of the students gave extensive comments supporting this idea. However, a significant number also felt that they were too time-consuming. A few also felt that they helped their grades, but a third of the students thought that multiple attempts made the quizzes too easy. Analysis of the online quiz survey data produced three principle components (or factors) that accounted for 70% of the variation in the original 17 questions (Figures 2 and 3). The first factor, which alone accounted for 30% of the variation, was positively correlated with survey questions that asked about the effect of the quizzes on learning. Hence, it was interpreted as a general instructional value factor, which is supported by positive comments that the quizzes helped them learn, helped their grade, and prepared them for the essay exams. The second component was positively correlated with questions about wanting more quizzes and whether they were helpful and negatively correlated with questions about how time-consuming the quizzes were and whether they wanted fewer quizzes. This interpretation corresponds with comments that the quizzes were helpful but that they are too time-consuming and too long. The third factor was positively correlated with questions asking about feedback and fairness and seems to correspond with the comments that these quizzes were helpful (Figures 2 and 3).

4.2 Concept Mapping Components of Variation

The most frequent student comment about concept mapping was that it promoted understanding of the biology concepts covered in the course. In addition, nearly a third of the students felt the maps helped them do well on the essay exams. However, negative comments indicated that concept mapping is too time-consuming (32%) or too difficult to master and that inability to be successful at mapping frustrated them and may have impeded their understanding of biology concepts. Principle components analysis of the concept mapping survey data extracted three factors together accounting for 67% of the variation in the original 17 survey questions (Figures 2 and 3). The first factor was positively correlated with survey questions about whether this assessment was goal-oriented, required thought, and promoted understanding. Factor 2 was positively correlated with statements that maps were to time-consuming and too frequent and negatively correlated with wanting more concept mapping. The third factor was interpreted as reflecting positive aspects of concept mapping including that the effort required was reasonable, that they were challenging and that they were carefully chosen. Factors one and three seem to correspond to student comments that concept mapping promoted understanding and that they helped them do well on exams, whereas factor two seems to be most related to the negative comments about them being too time-consuming and frustrating (Figures 2 and 3).

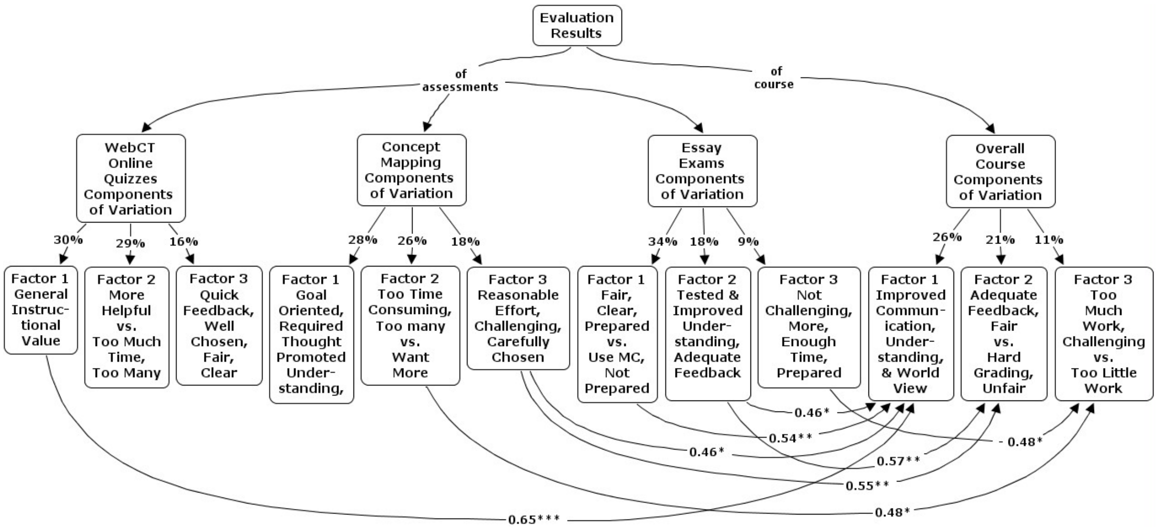

Figure 2. Concept map of evaluation results showing principle components for each survey instrument. Interpretations of each component are based on their correlations with the original survey variables. Percentages indicate variance explained by each factor. Intercorrelations of assessment components with overall course components are shown by the crosslinks and correlation coefficients. Correlation coefficients are shown for significant correlations between factors. Asterisks indicate significance of correlations: * = 0.05, ** = 0.01 and *** = 0.001. Eight significant correlations out of 27 considered are greater than expected by chance alone.

4.3 Essay Exam Components of Variation

Student comments presented a bipolar view of essay exams. The majority of comments were positive about this assessment type. Many students stated that essays either required or promoted understanding of biology concepts and that they were fair and effective assessments of their learning. Many also just liked this exam format over multiple choice exams. However, a significant number of students did not like the essay exams and suggested use of multiple choice exams instead. A few felt that essays were not an accurate reflection of their understanding and that they penalized students who did not write well. A few also felt that the class did not prepare them well for the essay exams. Principle components analysis of the essay exam data extracted three components that together explained 61% of the variation in the original 23 survey questions (Figures 2 and 3). The first factor was bipolar and alone explained 34% of the variation. Positive correlations with factor 1 were that the exams were fair and clear and that students were prepared for them. This factor was negatively correlated with the opinion that multiple choice should be used and that students were not prepared. Hence, this factor reflects a clear preference for the essay exams versus a preference for multiple choice exams. Essay exam factor two was positively correlated with the belief that the essay exams tested and improved understanding and that students were provided with adequate feedback. The third factor, although explaining a relatively small portion of the variation, was positively correlated with the belief that the exams were not challenging, that more exams should have been given, and that they were prepared. These factors correspond well with the comments about essay exams. In particular, factor 1 reflects the strong dichotomy between preference for essay exams and preference for multiple choice exams (Figures 2 and 3).

4.4 Overall Course Components of Variation

Principle components analysis of overall course survey produced three factors collectively explaining 58% of the variation in the original 26 survey questions (Figure 2). Overall course component one was positively correlated with student opinions that the course improved their communication skills and understanding of biology and that it broadened their worldview. Thus, this component is clearly aligned with my stated course goals of promoting understanding of biology and science process and affecting their worldview to include the interrelatedness of all life. Overall course factor two was positively correlated with the opinion that adequate feedback was provided and that they were fairly graded and negatively correlated with the belief that the course was hard and unfair. Course factor three clearly reflects a contrast in opinion that the course was too much work versus that it was too little work (Figure 2). Hence, we might consider factors one to three as the course goals, fairness and workload factors, respectively. Comments regarding the overall course were not explicitly requested, but the dimensions of variation extracted from the overall course survey can be seen in the comments for each of the assessment types.

4.5 Relationships of Assessment Factors with Overall Course Factors

To assess the relationship of assessment types with the overall course evaluation, factor scores for each of the assessment analyses were correlated with the overall course factor scores. The rationale for the approach is that the overall course evaluation should be dependent to a large degree on the assessments employed. Examination of these relationships might then reveal aspects the assessments that are associated with deep approaches to learning. Correlation of the assessment factors with overall course factor 1 suggests that some aspects of each of the assessment types contributed to student beliefs that they had improved communication, understanding and worldview (Figure 2). Of these, two essay exam factors produced significant correlations including the fairness/preparedness factor and the tested/improved understanding factors. Concept mapping (factor 3) and online quizzes (factor 2) were also positively correlated with overall course factor 1 (Figure 2). Correlations of assessment factors with overall course factor 2 indicate that both concept mapping and essay exams are related to their impressions of course fairness. Concept mapping and essay exams also appear to contribute to student beliefs that course work load is too much and too challenging as reflected in correlations with overall course factor 3 (Figure 2).

4.6 Sequential Relationships Among Assessment Factors

The ability to communicate understanding of a concept may be the ultimate test of that understanding. Hence, it was deemed important to assess the contributions of online quizzing and concept mapping to student perceptions of essay exams. To this end, online quiz and concept map factors were correlated with the essay exam factors (Figure 3). Similarly, it was deemed important to explore student impressions of the contribution of the online quizzing (which largely tests vocabulary) to the concept mapping factors. Student impressions that concept mapping is reasonable (factor 3) and that online quizzing is of general instructional value (factor 1) were positively correlated with their belief that essay exams are fair and that they were well prepared (factor 1). That concept mapping is reasonable (factor 3) was also correlated with the belief that essay exams improve understanding (factor 2). Finally, the desire for more online quizzing was correlated with the belief that essay exams were not challenging and that they were well prepared (Figure 3).

There were no significant correlations of the 3 possible online quiz factors with concept mapping factor 1 (maps goal oriented, required thought, promoted understanding), but there were significant correlations with concept mapping factors 2 and 3 (Figure 3). There was a significant positive correlation between online quiz factor 3, which generally expressed positive attributes of these quizzes, and concept mapping factor 2, which was positively correlated with the negative impression that mapping was too time-consuming and too frequent. This suggests that the students who like the online quizzes the most also had the most trouble with concept maps. There was also a positive correlation of online quiz factor 1 with essay exam factor 3. This suggests some direct relationship of the belief in online quizzing's general instructional value with some positive attributes of concept mapping.

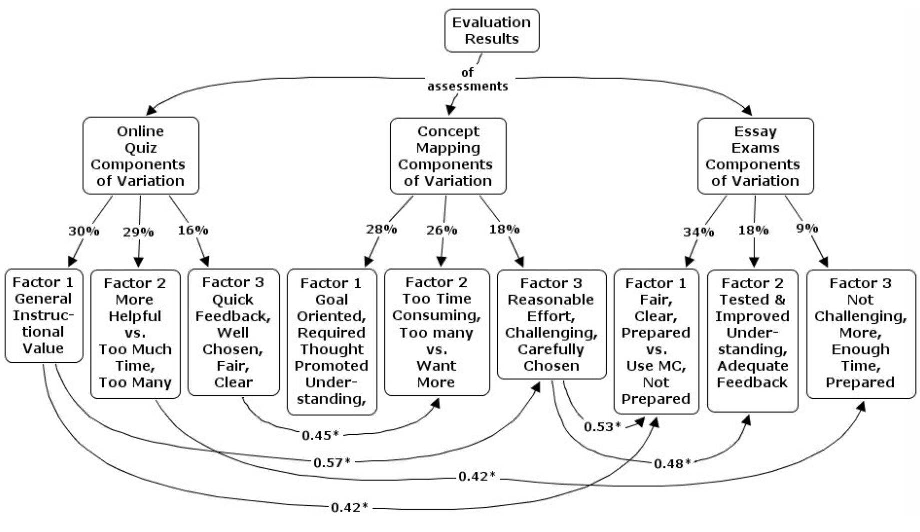

Figure 3. Concept map of evaluation results showing correlations of online quiz and concept mapping factors with essay exams and of online quiz factors with concept mapping factors. Percentages indicate variance explained by each factor. Correlation coefficients are shown for significant correlations between factors. Asterisks indicate significance of correlations: * = 0.05, ** = 0.01 and *** = 0.001. Six significant correlations out of 27 possible correlations are greater than expected by chance alone.

5 Hypotheses and Discussion

The results presented here examine some dimensions of variation in student opinions about a suite of three sequentially dependent assessment types and the overall course. For the online quizzing, the components of variation may be simplified to instructional value, helpfulness, and fairness. For the concept mapping, the major dimensions of variation can be summarized as promoting understanding, too time-consuming, and reasonableness. Essay exam factors reflected opinions related to bipolar fairness/preparedness, understanding, and not challenging. Finally, the overall course components can be summarized as reflecting course goals, fairness, and workload. Admittedly, it is risky to draw conclusions from a single small class of 23 students, so my conclusions are best stated as hypotheses for further study. Nevertheless, implicit in the design of this study were the a priori hypotheses that my alternative assessment would promote our overall course goals and that the sequential suite of assessments would culminate in a demonstration of deep learning as expressed by success on my essay exams.

5.1 Assessments and Deep Learning

Explicit goals of our course are to promote understanding of modern biology and science process, to help students develop their scientific reasoning skills, and to affect their worldview to include the interrelatedness of all life. Correlations of assessment factors with overall course factor 1 (Figure 2) suggests that all of the assessments contributed to the student's ability to communicate, understanding of biology, and broadened worldview.

Hypothesis 1: sequentially dependent assessments promote deep learning in science.

Research on student approaches to learning may help us explain how assessments can lead to conceptual understanding and metacognition. Student approaches to learning can be classified as surface and deep (Entwistle, 2001). Deep learners: 1) relate ideas to previous knowledge and experience; 2) look for patterns and underlying principles; 3) check evidence and relate it to conclusions; 4) examine logic and argument cautiously and critically; 5) are aware of the understanding that develops while learning; and 6) become actively interested in course content. Whereas, surface learners: 1) treat the course as unrelated bits of knowledge; 2) memorize facts and carry out procedures routinely; 3) find difficulty in making sense of new ideas presented; 4) see little value or meaning in either courses or tasks; 5) study without reflecting on either the purpose or strategy; and 6) feel undue pressure and worry about work (Entwistle 2001).

Clearly, we want our students to be deep learners and not surface learners. Surface learners will rarely develop deep conceptual understanding of any subject area, and they can be expected to do poorly on alternative assessments. Research on student approaches to learning has drawn attention to the significant influence of assessment procedures on learning and also led to identification of a third approach to learning often adopted by both surface and deep learner − the strategic approach. Strategic learners: 1) put consistent effort into studying; 2) manage time and effort effectively; 3) find the right conditions and materials for studying; 4) monitor the effectiveness of ways of studying; 5) are alert to assessment requirements and criteria; and 6) gear work to the perceived preferences of the teacher (Entwistle 2001). Thus, it appears that many students are keenly aware of the requirements for academic success and will modify their approaches to learning to ensure that they achieve that academic success, which is most often reflected by a high grade. Just as setting expectations can influence classroom behavior (Sufka and George, 2000), setting expectations about learning can influence student approaches to learning. If students accept expectations for learning and feel supported in achieving those expectations, strategic thinking may promote adoption of deep approaches to learning.

5.2 Alternative Assessment and Student Approaches to Learning

Correlations of concept mapping factors and essay exam factors with the fairness component of the overall course (factor 2; Figure 2) and with the workload component of the overall course (factor 3) suggest that student perceptions of these assessments have a great potential to affect student perceptions of the overall course. Student perceptions of unfairness and excessive workload might undermine student motivation and effort to perform the work of learning and undermine course goals.

Hypothesis 2: adequate support and acceptance of concept mapping and essay exams affect student approaches to learning and ultimately progress toward course goals.

Student acceptance of alternative assessments is key for achieving deep conceptual learning. Concept mapping and essay exams are relatively rare assessment types especially in science. Students may be conditioned to expect multiple choice exams and passive learning. Furthermore, students are spending fewer hours per week studying (Sufka and George, 2000), whereas learning in any domain requires a significant time commitment. Concept mapping and essay exams may require extra time because they are less familiar to students. Therefore, it is critical that students have adequate support in developing concept mapping and writing skills. Otherwise, they will consider them unfair and too demanding resulting in frustration and ultimately avoidance of learning. Student resistance can be overcome by providing adequate support and careful modeling of the concept mapping and writing processes (Quinn et al., 2004).

5.3 Concept Mapping for Concept Construction and Communication

Student perceptions that concept mapping was reasonable, challenging and carefully chosen (factor 3; Figure 3) was positively correlated to the fairness of essay exams and to the perception that they tested and improved understanding. This association is at least partly attributable to the fact that students were allowed to use their concept maps while writing their essays. However, it is also possible that the process of concept mapping helps students construct conceptual knowledge in preparation for good performance on the essay exams.

> Hypothesis 3: concept mapping is an effective tool for construction of conceptual knowledge and developing the ability to communicate deep understanding of that knowledge.

That concept mapping is an effective tool for deep learning has been well established (Novak, 2003). It appears that it not only promotes deep understanding, but also practice and mastery of the concept mapping process involve significant aspects of metacognition (Bransford et al. 2000). To an experienced grader, a student's concept map is a clear reflection of their understanding. Motivated students should also be able to detect and correct inconsistencies in their understanding as they map a concept. Such skills are fundamental to intellectual development and may help our students develop into reflective thinkers (Perry, 1968; King and Kitchener, 1994). Concept mapping is also an effective tool for developing effective written communication. Similar tools like mind mapping have long been used in composition classes for brainstorming prior to essay development. However, mind maps usually lack the hierarchical organization of concept maps and often converted to outlines prior to composition. Well constructed concept maps are as hierarchical as an outline, but retain crosslinks between hierarchies, which contribute to deep discussions of the concepts. Thus, concept maps can be effective tools for development of essays (Entwistle, 1995)

5.4 Surface Learning and Deep Learning

All online quiz factors were correlated with some essay exam factors, and online quiz factors 1 and 3 were correlated with concept mapping factors 3 and 2, respectively. Some of this relationship reflects the preference of some students for objective testing and their aversion to concept mapping, but the stronger correlation of quiz factor 1 with mapping factor 3 supports the value of online quizzing for concept mapping. Online quizzes were designed to promote surface learning.

> Hypothesis 4: assessments that promote surface learning such as online quizzes are a prerequisite for concept construction and communication.

Concept mapping may have the potential to be a bridge between surface learning and deep learning. However, it may be impossible to cross that bridge without first mastering the vocabulary for a concept. In other words, adequate surface learning may be a prerequisite for deep learning. Proponents of deep approaches to learning state that while the goal is deep understanding, it can not be achieved without first achieving a surface understanding (Entwhistle, 2001). The practical implication of this assertion is that students cannot explain or apply a concept without first learning the facts and vocabulary of a concept. So there must be some surface level expectation and assessment. Thus, assessments should be sequenced and coordinated to have maximum impact. They should first assure that students achieve surface learning including mastery of the basic vocabulary of the topic area. Then, assessments should promote construction of concepts including all of the major propositions and their interconnections. Finally, assessments should require construction of explanations of major concepts in preparation for communication about those concepts inside and outside the classroom. It is this last stage that should promote retention and transfer of conceptual knowledge about science that is the basis for scientific literacy (Halpern and Hakel, 2002). How faculty approach teaching affects curriculum design, teaching styles, and assessment choices. Many science faculty heeding the calls for science education reform have modified curricula and teaching to include more conceptual emphasis (Allen and Tanner, 2003; Udovic, 2002). However, most of us have neglected to modify our assessment approaches and continue to rely on surface level assessments. Class sizes and time demands of alternative assessments can be impediments to assessment reform. However, we must find a way to reform our assessments if we hope to achieve our goals for scientific literacy.

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BRAINBANK LEARNING – BUILDING TOPIC MAPS-BASED E-PORTFOLIOS

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Abstract. BrainBank Learning (BBL) is a suite of intuitive tools for learning of concepts and their content, and how they relate. The core of the suite is BrainBank®, the ontology of a topic map for acquired knowledge in a lifelong perspective. Topic Maps is a standard that defines an effective way of representing information. BBL is a web-based topic maps editor that works with standard Internet browsers. This means that educational institutions are not dependent on local installations or state of the art equipment to use this computer aided learning software.

Users enter the application through individual accounts. Topics are entered and described and eventually connected to other topics as associations with names and/or descriptions. Digital resources such as documents, pictures, movies and sound clips can be attached to the topics, and these resources can either remain external and be linked to or be uploaded to and stored in BrainBank. Topics can be grouped in themes or courses (e.g. classes), but they can also be interconnected across subjects and levels/grades and can thus serve as a scaffold in lifelong and lifewide learning perspectives.

A research project with 8th grade pupils from in Norway has shown that in addition to the well-documented advantages of using concept-based tools in learning, the pupils became aware that they were actually building their own content/knowledge management system, and they were additionally motivated by this.

1 Introduction

Today, humans need to cope with an increasing amount of information in most aspects of our lives. Not only are we overwhelmed with information, but also are the information and the channels through which we receive the information rapidly developing and changing. It is said that a person of today gets approximately the same amount of information in one edition of a newspaper as an average person would gather through his entire life in the Middle Ages.

There are at least two important factors that make the amount of information of today a real challenge: The work of discriminating information (to decide what to keep and what to ignore) and the process of transforming information to knowledge. As an attempt to assist these processes, the Norwegian company Cerpus AS has developed BrainBank Learning (BBL), a web based application that represents a systematic way of constructing and documenting knowledge during the learning process.

2 Background

One of the major challenges when it comes to learning is to move the learnt material from short-term memory and into long-term memory. Probably one of the most widely used methods of achieving that, is to digest the information one have been exposed to in one way or another, e.g. by taking notes. While there are several benefits of taking notes, there are also (mostly practical) drawbacks. In addition to the relative coincidental nature of such notes, the work can often be experienced as boring and unnecessary (especially if the learner is a young pupil). The learner rarely visits such notes later on (for reflection) and even more importantly, it can be rather difficult to support the capability to see and document relations and associations by taking notes on paper.

If storing the "notes" in a digital format (with an useful and effective user interface), however, many of the above mentioned problems are already solved. Firstly, the information ("notes") is can be stored and organized in a way that makes it easy to add new information and relate these to already existing information. Secondly, the stored information can be rearranged (re-organizing the structure of the information or for navigation and visualization) without having to re-enter it, and it is easily searchable. Thirdly, the possibility of making and representing associations between topics and subjects are much better when documenting digitally than when documenting on any static media (such as paper). The possibilities of storing massive amounts of information are also far better digitally than on paper or other static media. This last point makes it easier to gather documentation of knowledge from larger periods of time (or an entire lifespan) and to look back on previous knowledge and assess development.

There is another important aspect of documenting knowledge digitally, namely the possibilities for evaluation of the learner (especially important for teachers). If the students or pupils in a course or class document their learning digitally, it is possible to build solutions that enable teachers and supervisors to evaluate accurately. The assessment dimension is particularly promising if the digital production is organized and structured, e.g. as concepts maps [1].

Numerous computer-aided learning softwares exist to aid learning, web applications as well as offline systems. The tools vary from customized learning applications to edutainment and simple communication systems. However, several projects in Norway illustrate the need for a way of organizing and systematically navigation in the information chaos. Abundant digital resources and tools do not necessarily solve any problems if they by the end of the day contribute to increase the chaotic pressure of information on the learners.

3 BBL

BBL was designed to be a tool for meaningful learning [2] within a constructivist learning environment [3,4]. The tool was inspired by the ideas of knowledge building developed by Joseph D. Novak and colleagues [5]. Although the software has some similarities with concept mapping as defined by Novak [6-8], there are some clear differences: It is not hierarchical and it does not (yet) support a map-like graphical display of the knowledge structures. However, it is able to handle and store big and complex knowledge structures with attached digital content, and hence a powerful e-portfolio tool.

The first version of BrainBank was built as a simple web application with a database, (using WebObjects 5 from Apple). BBL of today is a web-based suite of intuitive tools for learning of concepts (topics) and their content, and how they relate. The core of the suite is BrainBank, the ontology of a topic map for acquired knowledge in a lifelong perspective. BBL is based on the Topic Maps standard (ISO 13250), including the XML format supporting the Topic Maps ISO standard (XTM) [9]. It was implemented using the Ontopia Knowledge Suite (by Ontopia, a leading topic map software vendor). BBL is currently hosted on a dedicated server, located and maintained at USIT (Centre for Information Technology), at the University of Oslo. As the Topic Map standard defines an effective way of representing information (through topics and associations etc.) [10], BBL now uses this Topic Maps technology to represent the data in the application. It is a web application that works with standard Internet browsers, which means that educational institutions are not dependent on any other local to use the application.

Users enter the application through individual accounts. Topics (keywords) that the learner meets during education activities are entered and described using BBL. The topics can then be connected by describing associations between them (Topic Maps provides excellent support for this). Thus the learner is creating his own associated network of topics and this represents his documented knowledge. This way of documenting in the learning process is good for the learner’s understanding of the area of study (placing knowledge in a context), as well as navigating and overview of the acquired knowledge later on (Figure 1).

To further describe topics and associations in BBL, digital resources such as documents, pictures, movie clips and sound clips can be attached to the topics. (These resources can be either linked to or uploaded to and stored in BrainBank).

Figure 1 The edit topic page in BrainBank Learning. The figure shows an 8th grade pupil's associations to the concept *World War II* ('2.verdenskrig', in Norwegian). Beneath the topic's name, there is a text field to give a definition/description of the topic. At the lower half of this page, there are three tabs (the grey area). These tabs represent associations from the current topic to other topics ('Assosiasjoner' in Norwegian) (currently selected), attached resources to this topic ('Ressurser' in Norwegian) and comments that are sent between the learner and the teacher ('Kommentarer' in Norwegian). The tab for associations is selected, and we can see all the seven associations made from *World War II* to other topics listed here, grouped by association types. The first type is called *is category for* ('er kategori for'), and it says that *World War II* is used as a category for Mussolini, the political fascist parti Mussolini was leading, and Hitler. The rest of the associations similarly illustrate the relations between the current topic (*World War II*) and other topics. An important notion: If we were clicking the names of the topics that are listed on this association tab, we would be taken to the view/edit-page of that topic (and hence we would se the names of the associations in the other direction)

BBL stimulates the learning process as the learner continuously reflects through and updates his own knowledge and stores it in BrainBank. This is because he has to discriminate received information to extract the essence of the information to document it in BBL, and also by relating new information to already existing knowledge by associating new topics to existing ones and describing the relation between them (Figure 2).

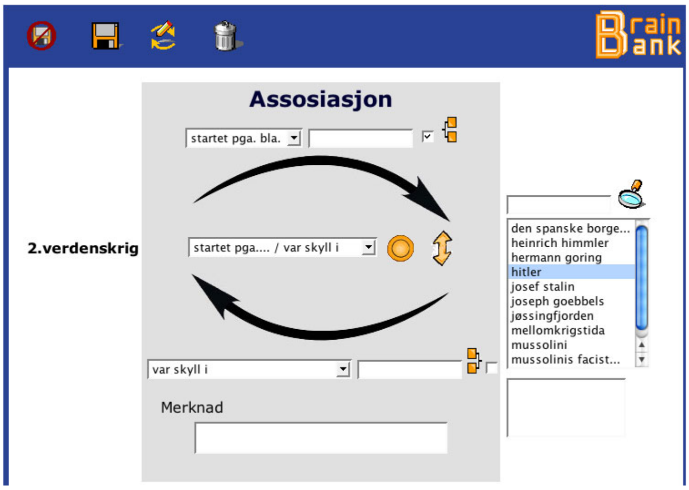

Figure 2 The edit association page of BrainBank Learning. Here, the user can create/edit an association from one topic to another. To the left, we see the current topic, which is *World War II* ('2.verdenskrig' in Norwegian). To the right, 'Hitler' is chosen as target topic from a list of topics available in the learner's BrainBank. (If the desired topic is not in the list, the user can search for it within the complete pool of topics in his/her BrainBank, using the search field above the list). The grey area in the middle is where the real action goes on. The learner has chosen an association type to use to connect the two topics from the popup menu. This signifies a description of the association in both directions (note the black arrows). In this case, the labels chosen are *started, because of (among other reasons)* ('startet pga. bla.' in Norwegian) and *was responsible for* ('var skyld i' in Norwegian). In total, this gives the following meaning: *World WAR II - (was) started, because of - Hitler*, and *Hitler - was responsible for - World War II*. If no satisfactory association types can be found in the popup menus (all three are synchronized), the user can create a new one, by entering the desired descriptive text in the text fields above and below the black arrows. This new type will then be available from the list the next time the user enters this screen. There are two check boxes on this screen

as well, and checking these causes the topics to be categorized relative to each other (the direction of the categorization depends of course on which box is checked). Category is a special association type for constructing hierarchical knowledge structures.

The learning strategy represented by BBL opens for both formative and summative methods for evaluating students, which makes it a promising instrument for modern forms for education. Teachers and supervisors can at any time take a look at what their students and pupils has documented in BrainBank. This way, they both evaluate progress and the knowledge documented. By examining the associations the students have made between topics, the teacher gets an impression on how much the students really understand of the area of study as well.

4 The BrainBank project

The BrainBank project has been a cooperative effort between PLP (Program for learning and practical pedagogy) at the University of Tromsø, Cerpus AS, USIT (Centre for Information Technology) at the University of Oslo, and Alsvåg primary and secondary school. The project was financially supported by The Norwegian Ministry of Research and Education, The Governmental Office of Education at Nordland County and Apple Computer Norway.

4.1 Project goals

The main goal for the 1st phase of the BrainBank project was to evaluate practical use of BBL and to find out if it helps improve learning to become more effective. It also aimed to discover how the learning process could be further improved.

Because of the short timeframe for this phase of the project, the focus has been on the learning process itself, more than on the outcome of the learning. It is hard to get any reliable results on how any specific method of learning will affect the learning outcome without conducting research over a long period of time (several years).

4.2 Test personnel and project timeframe

The project group consisted of ten girls and six boys in 8th grade (approx. 13-14 years of age) at Alsvåg barne- og ungdomsskole (Alsvåg primary and secondary school). Two teachers were also a part of the project. The project is roughly divided into three phases[1] with a total time span of minimum six years. This paper presents the results from the first phase, going from July 1st 2002- July 15th 2003.

4.3 Project methodology

The project was carried out along the lines of action research. Development and research have been tied up together in a common process, and this has colored the process in the project. A qualitative approach has been chosen, and these are the main activities used in the project:

- Observation of the project group (in their classroom)
- Observation of the pupils' brainbanks (in BBL)
- Interviews with teachers and pupils (individually and in groups)
- Questionnaire
- Informal conversations
- Written statements from the pupils

Some interviews, informal conversations and observation in the classroom were undertaken in the early stages of the project, but the main focus of the project activities was at the later stages of the project (when the pupils and teachers had had some time to learn how to use BBL, and had some experience from using it).

[1] Phase 1: 1 year time span, phase 2: 2 years, phase 3: several years.

5 Main findings

BBL has been used for individual work during teaching, individual work at the end of a lesson in class, individual in-depth studies, during group work and projects. BBL was found to work well within most educational methods, but some of the pupils (and the teachers) felt that they needed more time to work properly with BBL: 45 minute sessions were sometimes to short to acquire, digest and process the information, and then to document the new knowledge precisely as piece of the total knowledge map. These pupils asked for longer sessions.

5.1 Learning awareness

Initially, the pupils had problems coming up with a well-founded answer when asked to explain why they should use BrainBank. Neither were they able to write down satisfactory explanations of the key terms *keyword* and *category* from BrainBank. However, when some time had passed, observations of their work in BrainBank showed that in reality, they had gained quite a good understanding of the concepts of keywords and categories. With few exceptions, all of them had used both keywords and useful categories in BrainBank, even though they might not have been able to define them explicitly and independently of practical use.

In the later stages of the project, many of the pupils were able to formulate how BBL improved their learning. They had gained an explicit awareness of their own learning process. Based on the replies from the pupils (in interviews), especially two factors were identifiable; structure and order, and repetition of learnt material. Ten out of sixteen in the project group made statements related to structure and order. They felt it was better to structure and store the knowledge in BrainBank than on paper. (See Table 1 Statements from the pupils regarding reflection on the learning process.)

Pupils often think of repetition of learnt material as boring. Still, it is widely acknowledged that repetition is one of the best ways of *saving* knowledge. Seven out of the group of sixteen pupils said that BBL helped in remembering what they had learned. According to these pupils, BrainBank mainly helped because they could easily go back and take a look at what they did earlier, what they had written down of keywords and associations. The same pupils said that they regularly used BrainBank to repeat for themselves what they had learned (home or at school) (See Table 1 Statements from the pupils regarding reflection on the learning process.)

A third element that sticks out is that of awareness of learning. Some of the pupils say that they now pay more attention to *how* they are learning. The fact that the pupils had started reflecting on the structure of the learnt material and repetition in itself represent an improvement when it comes to how conscious the pupils are of their own learning. In addition, especially four pupils made explicit statements that clearly indicates that they have started a process of reflecting on their own learning process as such (See Table 1.)

All of these three main findings (structure, repetition and awareness of learning) are interesting to note in terms of using BrainBank to support and improve the learning process [6,7]. Here follows some of the pupils' self-expressed views on their own learning when using BrainBank (all translated from Norwegian, obviously).

Structure and order:
"We can save things, so we won't forget it. It's simply to enter BrainBank, and there we have it. It's easy to save and easy to retrieve. We learn more and more through the years."
Repetition:
"You kind of get a repetition of what is learned when typing it into BrainBank. When I'm in 9th grade, I can look back on what I learned in 8th grade."
Learning awareness:
"You become more aware of what you read when writing keywords. You pay more attention. When I do my homework more in-depth, because I'm going to find keywords."
"I have to read more concentrated to be able to make keywords and see associations."
"We have to really know *the material. We can't just copy the book. We have to be more prepared for class. I do prepare better for class.*

Table 1 Statements from the pupils regarding reflection on the learning process.

5.2 Motivation

Pupils and teachers in the BrainBank Project express that they think BBL is an exciting tool that is easy to use and to learn. Here follows some quotes from the pupils to illustrate the pupils' enthusiasm for the new elements BrainBank represents (all translated from Norwegian):

Motivation:
"I'm so proud when I see how many keywords I've got in BrainBank!"
"We think it's easier. Notes on paper can easily be lost or destroyed."

Table 2 Statements from the pupils regarding motivation.

These statements (Table 2) are representative for the entire project group. One can raise the question if it is BBL that gives increased motivation among the pupils, or if it is simply the use of computers in general. Previous studies have reported that the use of ICT generally increases motivation. It is hard to separate the use of BBL from the use of computers in general with regards to motivation in such a short period of time as this first phase of the BrainBank project. But it might be an indication that almost all of the pupils expressed that they would like to use BBL in more subjects than the two picked for the project. Some even say that they would like to use BBL in all subjects, and that it would help them see connections between the subjects, e.g. languages etc.

5.3 Summary of the activity in BBL during the project

To summarize the activity among the pupils during the project, key numbers are presented in Table 4:

	Number of topics (keywords) registered	Number of associations
Low point	85	9
Average	225	38
High point	300	78

Table 3 Activity in BBL during the project.

As the table shows the number of associations is relatively low compared to the number of concepts. The most apparent reason is that BBL was used as a tool in "traditional" activities, and as the teachers did not focus on associations for all educated themes, the pupils were not always given time to build associative structures. Moreover, BBL as opposed to mind mapping and concept mapping software did not have a map-like graphical interface. The lack of a good graphical visualization of the associations probably made it less apparent for the pupils why they should undergo the relatively time-consuming process of building a semantic associative map.

5.4 Challenges

One issue that came up is how detailed and how often the teachers should evaluate the pupils. BBL offers possibilities of accurate and detailed evaluation, because of the teachers' possibility to look at the pupils' work. Since the pupils' work in BBL includes associations (and hence much of the pupils' understanding in the area of study), the teachers have the option of seeing how the pupils think of the relevant topics and their place in the context. However, for a teacher to do this kind of detailed evaluation of many pupils is time consuming. So, even if this challenge is not related directly to BBL (a teacher can simply choose not to use it for evaluation) the new options of assessment bring this issue out into the light. A possible answer to this could be to automating this by using techniques like latent semantic analysis [11] or by comparing topic maps: If some pupil's topic map is widely apart from the other pupils and/or the teacher's, you may take this as signal to talk to the pupil.

6 Conclusion and the road ahead

The project concludes that 8th grade pupils are motivated by BBL and that BBL may stimulate meta-cognitive processes and reflective learning. Moreover, the results suggest that BBL is a promising strategy for associative learning and adapted education. BBL represents and supports a learning strategy that places the learner in the centre of the learning process. The idea is that the learner himself is (to a certain extent) building and documenting his own knowledge structure, centered on the actual content of the material he has worked with. According to the results from phase 1 of the BrainBank project, this strategy seems successful in several aspects. Previous experiments has shown that concept mapping tools facilitate meaningful learning and the creation of powerful knowledge frameworks that not only permit utilization of the knowledge in new contexts, but also retention of the knowledge for long periods of time [7,8]. In the ongoing follow-up study we will investigate more closely if similar results could be obtained without the map-like visualization.

Up till now (at least in Norway) much of the use of ICT in education and learning has been focused on the advantages of using digital media when it comes to communications, storing and motivation. There should be a greater focus ahead on developing systems that can help in *internalizing* the information available on the Internet (and other digital media) to build knowledge. Systems like BBL have several advantages in this picture. Firstly, when documenting knowledge in this tool, that documenting process helps the learning itself. Secondly, when the knowledge is documented, the system will work as a kind of personalized "encyclopedia" to the user. This lexicon is actually intuitive to navigate and search since everything is built on structures that user has made himself. In addition to that, as BBL of today (version 2.2) is using Topic Maps (and XTM) technology, navigation is made even more powerful (through associations etc.). Thirdly, in a larger perspective, if merging some of the users' topic maps, this kind of structure can represent the documentation of knowledge inside an organization or any other body.

Many issues for further research and development have appeared during this project. Several of those require a longer period of time to research than what the first phase of the BrainBank project offered. The following questions would be interesting to try to answer (through further research):

- How to ensure that BBL contributes to cooperative work between different subjects?
- How does BBL affect different ways of working, the learner's learning process and the outcome of the learning?
- How can the teacher most efficiently follow up on the individual learner's development through BBL?
- How can BBL best be used to aid the learners' reflection on their own learning?
- How can BBL best be used as a part of the learning habits of the learner, i.e. that the learner uses BBL on his own initiative?
- How can the teacher best guide the learners and help structuring of topics and associations in BBL?
- Would it help the learning process if the learners could explore end utilize directly each other's brainbanks?
- How can BBL best be used together with other e-learning resources (such as CmapTools, which already supports XTM 1.0, tools for building learning designs and e-curriculums, latent semantic analysis, learning management systems, etc.)?

To follow up all of these issues more time and resources is required. However, the issues reported here are good starting points for the continuance of the BrainBank project (further phases).

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"GOOGLING" FROM A CONCEPT MAP: TOWARDS AUTOMATIC CONCEPT-MAP-BASED QUERY FORMATION

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Abstract. Electronic concept mapping tools provide a flexible vehicle for constructing concept maps, linking concept maps to other concept maps and related resources, and distributing concept maps to others. As electronic concept maps are constructed, it is often helpful for users to consult additional resources, in order to jog their memories or to locate resources to link to the map under construction. The World Wide Web provides a rich range of resources for these tasks—if the right resources can be found. This paper presents ongoing research on how to automatically generate Web queries from concept maps under construction, in order to proactively suggest related information to aid concept mapping. First, it examines how concept map structure and content can be exploited to automatically *select terms to include in initial queries*, based on studies of (1) how concept map structure influences human judgments of concept importance, and (2) the relative value of including information from concept labels and linking phrases. Second, it examines how a concept map can be used to *refine future queries* by reinforcing the weights of terms that have proven to be good discriminators for the topic of the concept map. The described methods are being applied to developing "intelligent suggesters" to support the concept mapping process.

1 Introduction

Concept mapping (Novak & Gowin, 1984) is widely used to enable individuals at many different levels—from elementary school students to scientists—to construct new knowledge, externalize knowledge in a human-usable form, and share and compare that knowledge to advance human learning and understanding. To facilitate this process, the Institute for Human and Machine Cognition (IHMC) has developed CmapTools (Cañas *et al*. 2004a), a suite of tools to support generating and modifying concept maps in electronic form, interconnecting those maps, and annotating them with additional material such as images, diagrams, and video clips to develop rich browsable knowledge models. CmapTools provides a convenient framework for building and sharing multimedia concept maps and organizing them into linked knowledge models. A recent research focus is to augment CmapTools with support methods to aid the users' knowledge construction process. Developing tools to guide Web search during concept map construction is an important part of this effort: The Web provides an enormous body of information, but finding the right information may be difficult. Carvalho, Hewett and Cañas (2001) presented methods for exploiting the propositional and hierarchical nature of concept maps to improve filtering and ranking of results from search engine queries generated by users while browsing or constructing concept maps. Those methods have been successfully applied in a CmapTools search aid which has proven popular with users: It enables users to initiate Web searches for information that is related to a concept within the context of a concept map. This paper presents continuing research aimed at developing proactive "intelligent suggesters" to automatically provide information during concept map generation and access (e.g., Leake *et al*. 2003). In particular, it describes methods for automatically generating queries from concept maps, in order to provide users with related information as they build knowledge models. The methods identify important aspects of a concept map under construction and exploit this information (1) to generate queries to Web search engines, (2) to automatically refine those queries, based on returned results and the current concept map, and (3) to filter returned results. The methods exploit the structure of concept maps, combining structural information with simple term-based techniques in a robust framework that can be applied without requiring additional domain knowledge or full natural language processing. Initial results from this effort have been incorporated into CmapTools (Cañas *et al*., 2004b).

The paper begins with an overview of the CmapTools software and its built-in methods for enhancing Web searches. It then describes recent research results on developing extended methods for automatic query formation based on concept maps. Section 3 studies factors affecting how information from a concept map should be used for initial query generation. Section 4 describes our approach to automatically refining queries by exploiting concept map information, and Section 5 describes how the pieces are combined into an end-to-end system for automatic, concept-map based query generation. This work provides a toolbox of approaches, which, taken together, provide an end-to-end approach to automatic querying based on concept maps.

2 CmapTools and the CmapTools Search Enhancer

CmapTools is a suite of tools for generating and sharing concept maps in electronic form. CmapTools supports generating and modifying concept maps, as well as adding navigational links from concepts to other concept maps and multi-media material such as images, diagrams, and video clips, enabling the construction of rich knowledge models. The tools facilitate the storage and access of concept maps on multiple servers, providing the network services required to support knowledge sharing across geographically-distant sites. The CmapTools network tracks additions of new knowledge models as they become available, and users can search for information to refine and extend their concept maps, or to link their concept maps to relevant shared concept maps and multi-media material. In addition, integrated collaboration tools empower groups of users to construct concept maps simultaneously or to engage in discussions of the information in the concept map by posting notes or by opening discussion forums. Figure 1 shows a knowledge model displayed by CmapTools. The tools are freely available for nonprofit use, and have been downloaded by users in over 130 countries. Concept mapping with CmapTools has been used successfully to facilitate learning in educational settings, for capture and management of expert knowledge, and for just-in-time training. Full information is available from http://cmap.ihmc.us.

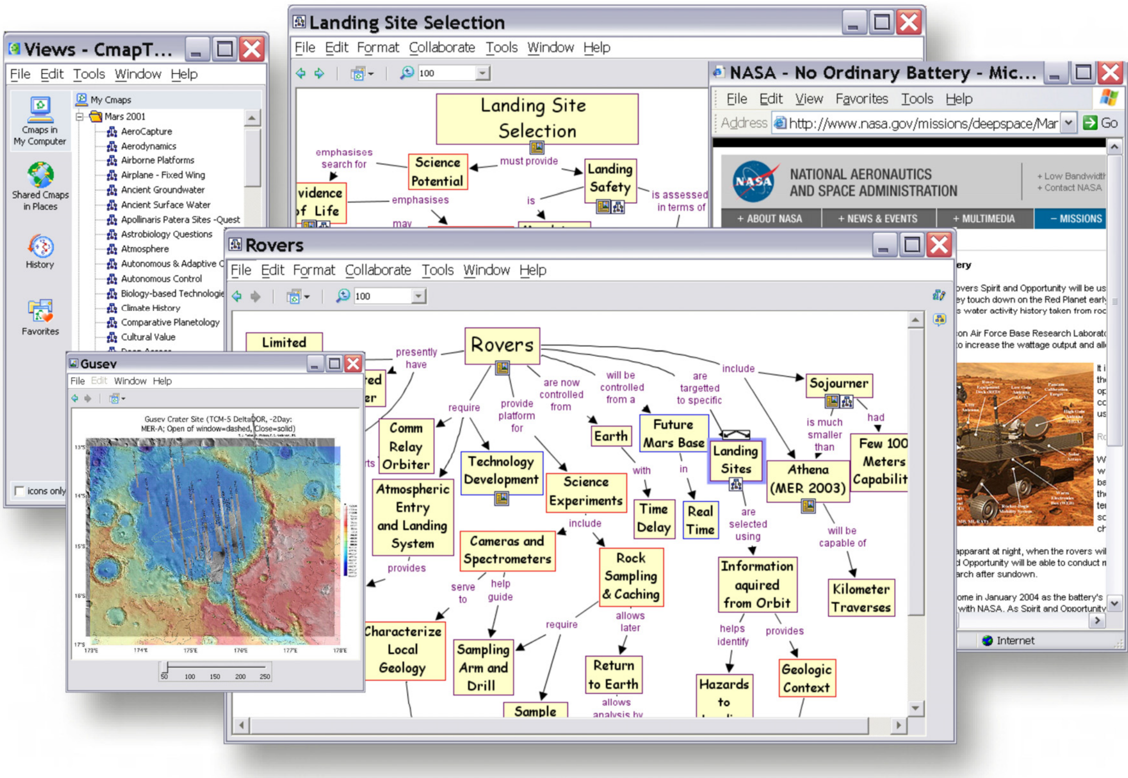


Figure 1: Knowledge model on the Mars domain

During concept mapping, access to appropriate Web-based resources can play a valuable role in aiding concept map construction. A current effort in the CmapTools project develops "intelligent suggesters" to aid in tasks such as *knowledge expression*, e.g., choosing terms to use in a concept map; *knowledge connection*, e.g., determining propositions to include or images, video clips, or other resources with which to annotate the nodes in a concept map; *knowledge communication*, e.g., presenting relevant concept maps to users developing related knowledge models; k*nowledge comparison*, to aid users in focusing on differences between their own and others' conceptualizations; and *topic selection*, to determine which additional concept maps to construct.

CmapTools provides a search tool, which takes queries based on a concept map—either under construction, or being browsed—and searches the Web (and/or CmapServers) for information related to the map. The user can easily and concisely specify the context of the search in a concept map, and that context is used for the automatic construction of queries. The Web-search algorithm allows the user to select a concept and ask the system to search for Web information that is relevant to the concept within the context of the concept map. The process consists of: (a) Analyzing the concept map to prepare a relevant query to use in searching the Web, (b) Retrieving relevant documents from the Web, (c) Ranking the retrieved Web pages according to relevance, and

(d) Presenting the results to the user. To generate the query, key concepts are selected from the map to reflect the domain of the map. These include the selected concept itself, the root of the concept map, and the map's authority nodes, nodes with the greatest number of incoming links from other nodes (a detailed explanation on selecting key concepts from a concept map is presented in Section 4 below). Based on the query, the tool retrieves Web pages to build a collection of documents. We have developed a meta-search engine, based primarily on Google (Brin & Page, 1998), to retrieve an initial set of documents from the Internet. Once retrieved, these documents are added to a cache for ranking. The ranking is based on comparing distance matrices calculated from the concept map and from each of the candidate documents. The purpose of the distance matrices is to favor documents which may contain propositions similar to the ones found in the map and those containing concepts that appear close to the root of the map. The top ranked documents are presented to the user. In a human subjects experiment, subjects judged the algorithm's rankings superior to those of traditional search engines, highlighting the value of exploiting contextual information to rank search results (Carvalho, Hewett and Cañas 2001). In practice, the tool has proven popular with users.

3 Using Concept Maps to Guide Automatic Query Generation and Refinement

Search engines provide access to a vast and ever-growing repository of information on the World Wide Web. However, finding relevant information remains challenging, because of the need to formulate queries to select on-point resources from the enormous range of possibilities. Users often generate very short queries (in a study of over a million queries to the Excite search engine, Spink *et al*. (2001) found that 60% of queries were one or two terms long), making query ambiguity a serious problem. Users may be inexperienced in selecting suitable keywords, may not know enough about the domain to select good query terms, or may simply overlook useful keywords. Some research addresses these problems by automatically augmenting user queries based on the task context, e.g., to make related suggestions as users read or write a document (e.g., Budzik *et al*., 2001). Our hypothesis is that the rich structure of concept maps can be exploited to automatically select effective keywords for Web search queries. Our research focuses on how to automatically generate queries for information related to a concept map under construction, and then to automatically refine those queries by analyzing the returned results in context of the original concept map. Our research strategy is to examine particular facets of the process, and the factors that affect them, in order to fill in pieces of the puzzle of how to exploit the nature of concept maps to guide search.

Specifically, we are studying three questions: (1) Can concept map structure be used to identify important concepts in a concept map?, (2) Are labels of those concepts sufficient to retrieve information related to the map?, and (3) Can query terms be refined automatically, based on analysis of their results and the maps from which they were generated? Because the goal of the retrieval process is to present *useful* suggestions, the ideal method for evaluating result quality would be an end-to-end evaluation, in which subjects directly assessed the usefulness of system suggestions. However, to guide the incremental development of the methods, it is crucial to be able to assess incremental steps for which human-subjects evaluations would be impractical. Consequently, the evaluations reported here use modified versions of information retrieval metrics, designed to test properties which we hypothesize to correlate with usefulness in practice. Guided by the results of these initial experiments, we have implemented a prototype system, and we are currently developing human subjects experiments to directly evaluate the usefulness of the full system. Results of a human-subjects study of a "concept suggester" implementing initial results from this research effort are reported in Cañas *et al*.(2004b).

4 Using Concept Map Topology to Weight Concept Terms

Web search engines limit query size (e.g., Google's query size limit is 10 terms). Thus a challenge for automatic query generation is to generate short queries focusing on the most important terms in a concept map. To achieve good recall, some of the terms should be selected for their quality as descriptors of the topic of the map. To improve precision, others should be selected for their ability to discriminate between documents. Ideally, topic descriptors will reflect the information that users will consider most relevant. This is hard to assure, however, because user importance judgments may depend on many factors, such as the structure of the map, the specific content of its concept labels and linking phrases, or the user's focus of attention when adding concepts to a map under construction. To develop robust methods that can be applied without knowledge engineering or full natural language processing, we have studied whether concept map structure can be used to predict concept importance, independent of the content questions which would require "understanding" the concept map.

To study how concept map structure influences human predictions of concept importance, we developed three candidate models of how structure affects concept importance (Leake *et al*. 2004). Some of the factors considered by our models are inspired by general guidelines for constructing "good" concept maps, taken from the concept mapping literature (Novak & Gowin, 1988), e.g., reflecting the importance of concept maps' hierarchical structure by weighting upper and lower concepts differently. Others are inspired by methods for analyzing the topology of hyperlinked network structures (Kleinberg, 1999), e.g., that nodes may be characterized based on outgoing and incoming connections as "hubs" or "authorities," where, e.g., authority nodes tend to have many incoming links. This view suggests the hypothesis that hub and authority nodes may play a significant role in describing the map's content.

Our models consider several structural influences on concept importance including (1) distance of a concept to a root concept, measured in terms of the number of links on the shortest path to the root concept in the concept map graph, (2) connectivity of a concept measured in terms of the number of incoming and outgoing connections, and (3) the concept's global connectivity to the root concept measured by a "path frequency" (PF) measure. In addition, models that consider multiple influences have parameters to weight the different structural influences. The three models, CRD, HARD, and PF, are summarized in Table 1. For CRD, the model parameters α, β, and δ adjust the effect of the number of incoming connections (i), the number of outgoing connections (o) and the distance to the root concept (d). For HARD, the model parameters α, β, and γ adjust the effect of authority (a), hub (h) and upper nodes (u) (nodes appearing near the top of the concept map). The values for authority, hub, and upper nodes correspond to the concept's role as an authority, hub, and upper node, while the upper weight reflects proximity of a concept to the root concept (for full details, see (Leake *et al.* 2003)). PF counts the number of distinct paths that reach a given concept, traversing the paths of the concept map graph starting from the root concept (n), and requires no parameters.

Connectivity Root Distance (CRD)	$W(C) = (\alpha \cdot o + \beta \cdot i) \cdot (1/(d+1))^{1/\delta}$, $\alpha, \beta \geq 0, \delta \geq 1$
Hub Authority Root Distance (HARD)	$W(C) = (\alpha \cdot a + \beta \cdot h + \gamma \cdot u)$, $\alpha, \beta, \gamma \geq 0$
Path Frequency (PF)	$W(C) = n$.

Table 1: Models for assessing concept importance.

To our knowledge, no previous studies have explored the role of such factors in human judgments of concept importance. We conducted a set of experiments involving 20 subjects admitted to Indiana University, using concept maps specifically designed to investigate structural influences by varying factors such as the degree of connectivity or the distance to the root node of certain concepts in the map. The maps' concept and link labels were replaced with random letter combinations, in order to observe structural influences independently of map content. Subjects were presented with pairs of concepts, and asked to select the more important one, or to indicate that both were equally important. We then fitted the models to the subjects' preferences by adjusting the models' parameters using a hill-climbing algorithm. The results revealed two trends in structural effects on concept importance: (1) both authority nodes and nodes with incoming connections are considered more important than hub nodes or nodes with outgoing connections, and (2) nodes close to the root node are considered more important than nodes more distant from the root node (Leake *et al*. 2004). These results enable us to model structural influences on concept importance when selecting terms from a concept map to include in a search engine query, by summing the weights of the concepts in which the term occurs and using terms with the highest weights as query terms.

5 The Sufficiency of Concept Labels to Guide Retrieval

In the weighting method described in the previous section, links between concepts influence the choice of concepts, but linking phrases themselves are not reflected in the set of search terms. Thus an important question is whether concept labels, combined with information derived from concept map structure, are sufficient for query generation. Informal results suggest that the prevalence of generic linking phrases (e.g., "has", "includes", "consists of") may make linking phrases less informative, decreasing their usefulness for an automatic system that cannot determine their specific meanings. However, to our knowledge, no controlled studies have examined this hypothesis. To investigate the effects on retrieval of concept-label-based queries compared to queries also reflecting linking phrases, we performed experiments comparing two types of queries using terms extracted from the concept and link labels in a concept map: (1) queries using terms selected from one or several concept keywords, or (2) queries using terms from a predefined ratio of concept labels and linking phrases. The queries were submitted to Google, and the terms appearing in the Web pages and other text documents returned by Google were then compared with the terms in the concept map from which the keywords were extracted. Terms were compared using two metrics, an adaptation of the Jaccard coefficient (a commonly-used association coefficient), and a coverage measure which we defined for this task. Table 2 below shows the measures.

S(Q,M,D), the modified Jaccard coefficient, measures the similarity between a document *D* and a concept map *M* as the proportion of terms in a retrieved result that are in the source map, but are not in the query *Q*. If the set of search results for a given query is empty, the measure for that query is considered to be 0. *C(Q,M,D)*, our coverage measure, is the ratio of shared keywords in *D* and *M* to the number of keywords in *M,* not counting the keywords in *Q*. The measures' values range from 0 (no similarity or coverage) to 1 (identical or full coverage).

$$S(Q,M,D) = \frac{|(D \cap M) - Q|}{|(D \cup M) - Q|} \qquad C(Q,M,D) = \frac{|(D \cap M) - Q|}{|M - Q|}$$

Table 2: Comparison measures for concept maps and Web documents.

For the experiments, we randomly selected ten concept maps from the Mars 2001 knowledge model (Briggs *et al*., 2004). In each experiment, a set of queries was computed, differing in the selection and number of concepts and linking phrases from which the keywords were drawn. Table 3 summarizes the average results of comparisons between concept maps and documents across the ten concept maps and the set of queries submitted to Google. The results suggest that concepts are critical in the search for information and search terms extracted from more than one concept yield better matching results. In contrast, linking phrases play a subordinate role in the search for information. Compared to queries from concepts, queries constructed only from linking phrases returned documents exhibiting little similarity to the concept maps from which they came. While some linking phrases aid in finding information somewhat similar to a concept map, they were generally far less effective, and often insufficient, for finding suitable information compared to concepts. Thus, we hypothesize that concepts are generally more valuable to improve precision of Web queries than linking phrases. This provides support for the ability of concept-based queries, such as those based on terms selected by our previous models, to retrieve resources with good coverage.

single concept		*link-link-link*		*link-concept-link*		*concept-concept-concept*	
Jaccard	**Coverage**	**Jaccard**	**Coverage**	**Jaccard**	**Coverage**	**Jaccard**	**Coverage**
0.02669	0.12618	0.01493	0.11380	0.02445	0.18492	0.02915	0.25636

Table 3: Results from the Google concept-linking phrase experiments.

6 Learning to Refine Query Terms

The previous sections describe methods for selecting and weighting concept map terms to include in a query. However, the first terms generated for a Web search may not provide the definitive results. For human-generated queries, users frequently decide, based on initial results, to refine their queries or pursue new directions (in Spink *et al*.'s study, 52% of users' sessions involved multiple queries).

When seeking for material on a topic, it is natural to form queries using the most descriptive terms of the topic. Terms are *good descriptors* of the topic of a concept map if they answer the question "What is this concept map about?" As discussed in Section 3, topological factors are useful for finding good descriptors of the topic of a concept map. We conducted an experimental study, using the Mars 2001 knowledge model, to investigate the hypothesis that terms that have higher weighting values according to our topological models tend to be good query terms. This evaluation showed that although these terms are useful, queries composed of descriptors alone are not sufficient to assure high precision. To address this problem, we developed a new approach based on the notion of *topic discriminators*.

Terms are good topic discriminators if they answer the question "Which are the best query terms to access similar documents?" A term is a good discriminator for a topic if most documents that contain that term are topically related. Thus finding good topic discriminators requires finding terms that tend to occur only in the context of the given topic. We propose that both topic descriptors and discriminators play an important role in concept map retrieval: That including topic descriptors in queries is important for recall, while including topic discriminators is important for precision. We have developed a method to exploit this within an automatic query generation system, automatically refining query terms by dynamically extracting good topic discriminators from search results and combining them with good topic descriptors identified by means of topological analysis.

Identifying Topic Discriminators for Concept Maps: Given a collection of m documents and n terms we can build a m×n matrix H, such that H[i,j]=k, where k is the number of occurrences of term t_j in document d_i. We define discriminating power of a term in a document as a function $\delta: \{t_0,\ldots,t_{n-1}\} \times \{d_0,\ldots,d_{m-1}\} \rightarrow [0,1]$:

$$\delta(t_i, d_j) = \frac{\mathrm{sgn}(H^T[i,j])}{\sqrt{\sum_{k=0}^{m-1} \mathrm{sgn}(H^T[i,k])}}$$

Analogously, we define descriptive power of a term in a document as a function $\lambda:\{d_0,\ldots,d_{m-1}\}\times\{t_0,\ldots,t_{n-1}\} \rightarrow [0,1]$:

$$\lambda(d_i, t_j) = \frac{H[i,j]}{\sqrt{\sum_{k=0}^{n-1} (H[i,k])^2}}$$

We can also define the descriptive power of a term *t* in a concept map as W(*t*), where W is the weight of the highest weighted concept in the map containing *t* according to some model from Section 3.

These simple notions of document descriptors and discriminators share some insight with standard IR proposals (Jones 1972; Salton & Buckley, 1988). Another recurrent notion in IR is document similarity. Let $\sigma(d_i,d_j)$ stand for the similarity measure between documents d_i and d_j. This measure can be computed in terms of term descriptive power as follows:

$$\sigma(d_i, d_j) = \sum_{k=0}^{n-1} (\lambda(d_i, t_k) \cdot \lambda(d_j, t_k))$$

We are interested in identifying good topic discriminators to form queries that will result in high precision. Function δ allows discovering terms that are good discriminators of a *document*, as opposed to good discriminators of the *topic* of a document. Because our goal is to refine queries to best reflect the topic of a concept map, we propose a topic-dependant definition of topic discriminators based on the notion of similarity between documents. We define the discriminating power of a term in the topic of a document (or concept map) as a function $\Delta:\{t_0,\ldots,t_{n-1}\}\times\{d_0,\ldots,d_{m-1}\}\rightarrow [0,1]$ calculated as follows:

$$\Delta(t_i, d_j) = \sum_{k=0,\quad k\neq j}^{m-1} (\sigma(d_k, d_j) \cdot \partial(t_i, d_k)^2)$$

Thus the discriminating power of term t_i in the topic of document d_j is an average of the similarity of d_j to other documents discriminated by t_i. Therefore, a term's discriminating power on the topic of a document is computed using the definitions of document similarity and term discriminating power on a document.

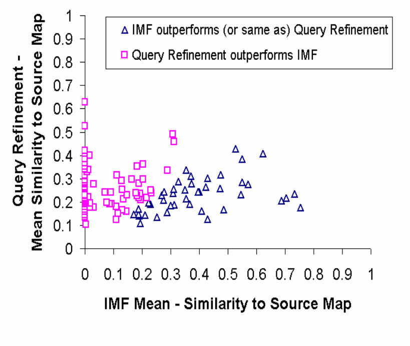
We claim that concept map descriptors can be recognized locally, by looking at the topology of a concept map. However, in order to find good discriminators of the topic of a concept map, as we mentioned earlier, the topology of the map is not sufficient. However, a relatively cheap *distillation* process has proven to be helpful to extract good topic discriminators. This distillation process consists of submitting a few queries to a search engine and using the information readily available from the search results to compute a Δ value for each found term. We argue that terms with high Δ value are good for attaining high precision. In the next section, we evaluate our methods for refining queries based on the notion of topic descriptors and discriminators.

An Experimental Test of Query Refinement: In order to test our proposal for learning to refine queries, we again used the Mars 2001 knowledge model. For each concept map, a baseline static method (described below) and our method for topic distillation were applied to select query terms. To evaluate the performance of these methods we computed the mean similarity of the returned results to the source concept map. We measure similarity as the proportion of novel terms (terms not in the query) in a retrieved document that are also part of the source map, using the function *S(Q,M,D)* described previously.

In our experiment, we use *Inverse Map Frequency* (IMF) as the baseline static feature weighting method. IMF is an adaptation of the standard IDF (*Inverse Document Frequency*) weighting scheme to measure the overall rarity of a term in a knowledge model. Thus, each term t in a concept map label was weighted as $IMF(t)=\log((1+|KM|)/|KM_t|)$, where *KM* represents the number of concept maps in the knowledge model (KM = 118 for the ``Mars 2001" model) and $|KM_t|$ stands for the number of concept maps containing term t. The IMF method was used to sort the terms occurring in a concept map. We then incrementally generated queries of increasing sizes, starting from a query of size 1 consisting of the most highly weighted term and incrementally adding terms in order of decreasing weight.

In our evaluation, we constructed a query for each concept in a concept map as a Boolean combination of terms occurring in the given concept plus the terms occurring in the map's root concept. For each query, we used the top 30 Google search results (if fewer than 30 results were returned, all were used). The search results were divided into 3 sets of equal size. In a three-stage evaluation, we used one of the sets for distillation and the other two for testing, rotating the roles of the sets at each stage. For each stage, the distillation data was used to learn an approximation of the discriminating power of each concept and the testing data was used for performance analysis. Only the "snippets" returned by Google were used for distillation, and the full documents were used for testing. (The *snippet* returned by Google is a text excerpt from the page summarizing the context in which the search terms occur.) The distillation phase in the query-refinement method consisted in computing the Δ value for the terms involved in a query to determine which terms are the best discriminators. For a fair comparison of the performance of the query-refinement method against IMF, we assured that queries were the same length by setting the size of the IMF queries to the number of terms occurring in the query resulting from the query-refinement method.

Figure 2 shows a scatter plot and table of results comparing the query-refinement method to the IMF method. We can see from the scatter plot comparing mean similarity between returned results and the source map that the query-refinement method outperforms IMF (64% vs. 36%) In the comparison table, we present the mean similarity confidence interval resulting from the query-refinement method, and we compare it against the mean similarity confidence interval resulting from applying the IMF method with query size adjusted as we explained above. This comparison table shows that the query-refinement method results in significant improvements over IMF.



	N	Mean	Standard Deviation	Standard Error	95% Confidence Interval
Query Refinement	118	0.2498	0.0903	0.0083	**(0.2335, 0.2661)**
IMF	118	0.1880	0.1955	0.0180	**(0.1527, 0.2232)**

Figure 2: Performance comparison of the query refinement method against IMF.

7 Combining the Approaches

The previous steps provide methods for automatically generating and refining concept-map-based queries. The following algorithm summarizes how the entire set of methods is combined in order to "Google from a concept map":

ALGORITHM:
INPUT:
C: a concept map.
T_σ: threshold for filtering irrelevant results.
q: number of queries per round.
BEGIN
//topological analysis
Apply topological analysis to assign a weight *W(c)* to each concept *c* in the concept map *C*.
//distillation
Submit *q* queries using the concepts *c* in *C* with highest *W(c).*
Compute Δ for each term in *C*, using only "readily available" results.
//search
Combine the concepts with highest *W(c)* value and the terms *t* with highest Δ*(t,C)* value to form *q* additional queries and submit the formed queries to a search engine.
//using concept map to filter results
Only display those documents *d* such that $\sigma(d,C) > T_\sigma$ where the content of *d* is approximated for this judgment using "readily available" information from search results.
END

The techniques discussed in the previous sections, and the results of the evaluations described there, are reflected in the design of the algorithm. Because it is possible to estimate concept importance based on concept map topology, and because concept labels tend to provide a good description of the content of a concept map for the purposes of retrieving similar information, the query formation process is based on concept labels: For the first round of queries, only labels of concepts with high descriptive power are used as query terms, where descriptive power is assessed by using the topological analysis models. For the *distillation* and *search* phases of the algorithm, the query refinement techniques discussed in section 6 are used to identify good discriminators of the topic of the map and to form queries that combine terms with high descriptive and discriminating power. As a final step, the returned results can be filtered according to the map, to improve the ranking of results; this is implemented in our system but cannot be described here due to space limitations.

8 Conclusion

This paper has described ongoing research on exploiting the information in concept maps to automatically generate and refine queries to Web search engines, to aid concept mapping. The component algorithms have been implemented in robust prototypes, and have been evaluated individually with promising results. The results provide initial support for the hypothesis that information extracted from concept maps can provide an effective starting point for automatically-generated search queries, and for the efficacy of the specific methods described. We are now designing experiments for an end-to-end human-subjects evaluation of the system as a whole, to directly assess subjects' judgments of the relevance and usefulness of the information provided.

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ELECTRIC MAPS

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Abstract. "*Electric maps*" are a new way of scaffolded concept mapping so that checking the accuracy of the relationships between concepts *is* a game. The "electric" concept map is obtained by replacing the connection lines of a common concept map with aluminum strips which are electric connections between the nodes and the linking phrases of the map. This electric circuit is closed within a folded cardboard so that it is not possible to see the connection lines from outside but only the nodes, some of which are provided with labels referring to concepts and/or relationships. Each box - node is provided with one or two contact points made through an access hole situated over the aluminum strip. The teacher can make these circuits from the concept maps of his/her pupils or, in the best conditions, the pupils can build them in order to involve other classmates. The pupils reconstruct this "puzzle" by exploring the structure with a connection detector. They draw all connection lines and complete the map by highlighting the labels suited to the nodes and to the linking words. This educational strategy suggested for pupils attending from the third to the fifth grade primary classes, has turned out to be exciting and very efficient to increase both the level of knowledge sharing, the accuracy and the meaningful comprehension to build each proposition.

1 Introduction

To better understand what are the electric maps and why we think they are very efficient in our reality, it is necessary to describe how they were originated and the context within which pupils started to use them.

1.1 The Circuit Game

According to one of our common science activities that we call "circuit game", the pupils shall highlight the electric connections, that are made up of glued aluminum strips, which are hidden inside a two-folded sealed cardboard provided with eight contact points from A to H. In order to find the connections of the hidden circuit the pupils try all connections between these contacts with a simple detector. For instance, if contacts A and C are touched with two copper wires of the detector and if the light-bulb of the detector is switched on, we can conclude that the circuit is closed and that there is a connection between A and C. On the other hand, if the light-bulb is not switched on while trying contacts A to D, it means that there is no connection between them. At the end of this game the pupils draw a map of the connection grid, open the cardboard and compare their drawing with the true circuit. In the most advanced form of this game the pupils build the hidden circuit by themselves while the others try to draw it by testing the connections.

1.2 Wire Card Quizzes

One day some of the pupils decided to replace letters A-H of the circuit game with questions and answers. If the light-bulb of the detector switched on it would signal the correct answer of a given question, thus changing a game of pure logic into a test to be submitted to other mates. Figure 1 shows one of the products of this initiative which is a grammar test.

Based on the circuit game, this quiz, which enables *to build and check the accuracy of the relations between concepts*, has given the hint to build the electric concept maps. The success of this path relies mainly on a sound educational principle of seizing, supporting and guiding the natural creativity and ability of pupils to find alternative ways to check and to learn, thus making them the authors of these choices. Therefore, the positive impact on both motivation and learning is not negligible.

1.3 Electric Maps

At this point there were all conditions to make a step forward: the construction of concept maps based on the same principle as the circuit game. As a matter of fact, for many years pupils have practiced the concept mapping in the scientific, linguistic, mathematical and historical domains as well as in other subject areas. It was clear why pupils were self-confident and positive since on the one hand they knew the experiment they wanted to carry out, and on the other they were fully aware of the ability necessary to achieve the final result. Therefore, the idea to build "electric" concept maps was encouraging and challenging both for us, the teachers, and for the pupils!

The electric map is obtained by replacing the connection lines of a common concept map with aluminum strips which are electric connections between the nodes and the linking phrases of the map. This electric circuit is closed within a folded cardboard so that it is not possible to see the connection lines from outside but only the nodes, some of which are provided with labels referring to concepts and/or relations. Each box - node is provided with one or two contact points made through a hole situated above the aluminum strip. The first electric maps, built by the pupils themselves, showed only the concepts in the relative nodes and had to be completed by drawing the connection lines and the linking words. This task was assigned to pupils of the parallel classroom. The pupils made the detectors*,* too, by means of 4.5 volt flat batteries, a wire and a light-bulb, whose screw was twisted at one of the ends of the electric wire. The other end of the wire was connected with one of the two foils of the battery. The connection between the two contacts could be checked by touching a contact with a plate of the battery and the other contact with the base of the light-bulb as shown in figure 1.

Figure 1. A *wire-card quiz* made by pupils along with the battery - bulb tester.

2 The Use of Electric Maps in Classroom Activities

This section shows the details of the activities suggested in the way they have been defined and prepared in the first trials carried out only on three educational units in the second half of the school year and only in three four grade primary classes out of five. The following descriptions can be applied to any educational domain although in our case we focused on the scientific, linguistic and mathematical subject areas.
During the classroom activity on a specific topic, the pupils build concept maps on paper and in some cases they transfer them on CmapTools software (i.e. Figure 2)

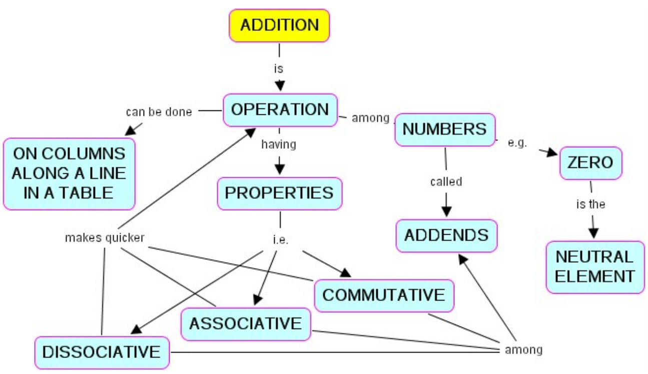

Figure 2 Example of concept map transferred on cmap format by a three grade pupil.

2.1 *Electric maps Built by the Teacher*

In the first phase the teacher uses some of these paper maps to build the electric maps to be submitted to pupils who shall complete exploring them with the detector (fig. 3).

Figure 3. Pupils looking for a connection

We devised two types of these electric maps.

2.1.1 Electric Map with all concepts and without links

Outside the first type of the electric map it is possible to see only the nodes provided with concept labels, organized in a pyramidal arrangement with the most important concept situated on the top without any connection line. Inside, in the hidden side of the cardboard, there are the aluminum strips that bind only the pairs of concepts that must be connected (fig. 4). After finding the connections with the bulb detector, the pupils must draw the relative lines and arrows between the concepts and suggest also the appropriate linking words that shall be written down on the map itself.

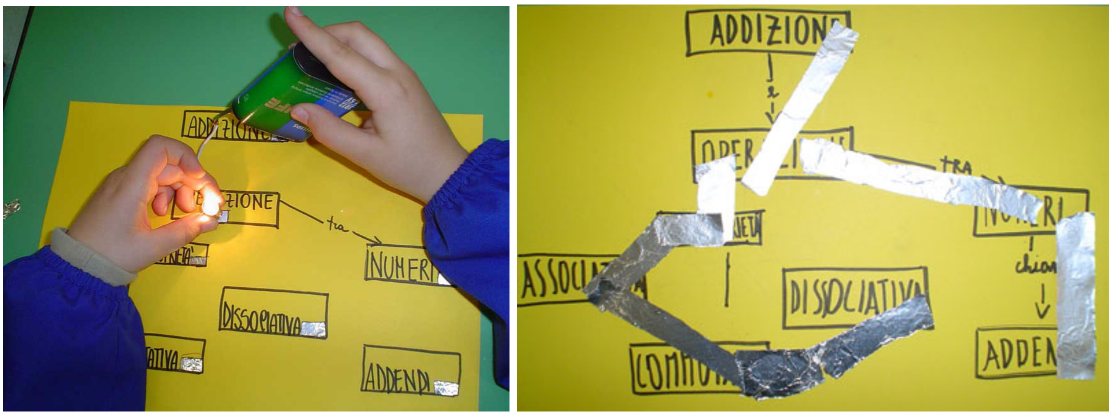

Figure 4. Outside and inside of the first type of *electric map* on addition built by children.

2.1.2 Electric Map with nodes, lacking for some labels and without links

As for the second type of electric maps, which is similar to the first type, some nodes are not provided with concept labels, and show, however, the relative linking phrases. Therefore, only the first or the second part of the propositions (concept – link phrase) is clear, and they are not provided with any connection lines. By means of their bulb detector, the pupils must find the connections between the linking phrases and the nodes that altogether complete the propositions; consequently, they must write the missing concept labels and draw lines and arrows.

Only in the second type of electric maps each node and each linking phrase is provided with two holes equipped with electric contacts otherwise pupils would identify which pairs of contacts are connected simply by checking the number and the arrangement of contacts. Furthermore, this system also prevents all nodes of the underlying circuit from being electrically connected among them. Moreover, compared to the positions held in the original map*,* the concept nodes are slightly moved vertically between one level and the other.

The two kinds of electric maps show gradual difficulties; the first type is simpler and when pupils master it they can work with the second type.

2.2 Electric Maps Built by the Pupils

In a following step the pupils can easily build the first type of electric maps. In our trial, this activity was carried out by groups of pupils who decided autonomously to share the tasks. An important step forward was made when the pupils asked to build the electric maps by themselves. After building and sealing the electric maps with the tape, the pupils submitted them to the mates of the parallel class.

3 Results

These electric maps allowed us to
1. assess the knowledge of each pupil,
2. highlight their cognitive processes (more easily than with other tools),
3. check how they master the concepts and the relative relations of hierarchical inclusion.
4. testify to the integration of new knowledge in the preexisting cognitive structure.

3.1 Motivation

It was very encouraging to remark that the pupils asked repeatedly to build the electric maps for all subject areas. We are aware that this motivation is the prime mover in both learning and knowledge. Also the expectation of pupil's wish to play was not disappointed at all!

3.2 Interaction between Pupils

The good level of interaction in the classroom played a significant role on the whole activity since it helped children to grow up and to make progress. As a matter of fact, while the pupils were working in groups, we often noticed that they corrected each other to choose the way to make the connections with aluminum and explained the reason for these choices. The pupils gave sound reasons and agreed on the position of the holes. In particular, they decided not to put the hole in the middle of the node since their mates would link the concept only with the one below and they decided to make all the holes in the same position. The construction of these electric maps showed the pupils' ability to use and understand the effective strategies for the organization of knowledge retrieval. This type of understanding was very important to design challenging and accessible puzzling tasks for their pairs. These group dynamics add value to the strategy of electric maps, because they testify to the knowledge and awareness of ones' own and others' cognitive process, thus starting *metacognition*.

3.3 Quality of Knowledge

The pupils have tested and completed these electric maps on a field of knowledge they knew about by using different strategies, thus making a custom-made product, even when these maps originated from the one built by the teacher. The need to decrease the hierarchical levels of the electric map to three or maximum four, encouraged the pupils to look for the most important concepts within the domains their knowledge was much wider. Common concept maps do not show this need that adds value to the strategy of the electric maps we are suggesting and turned out to be very efficient in strengthening the significance of current concepts.

The following map (fig. 5) summarizes the educational-pedagogic reasons of our trial.

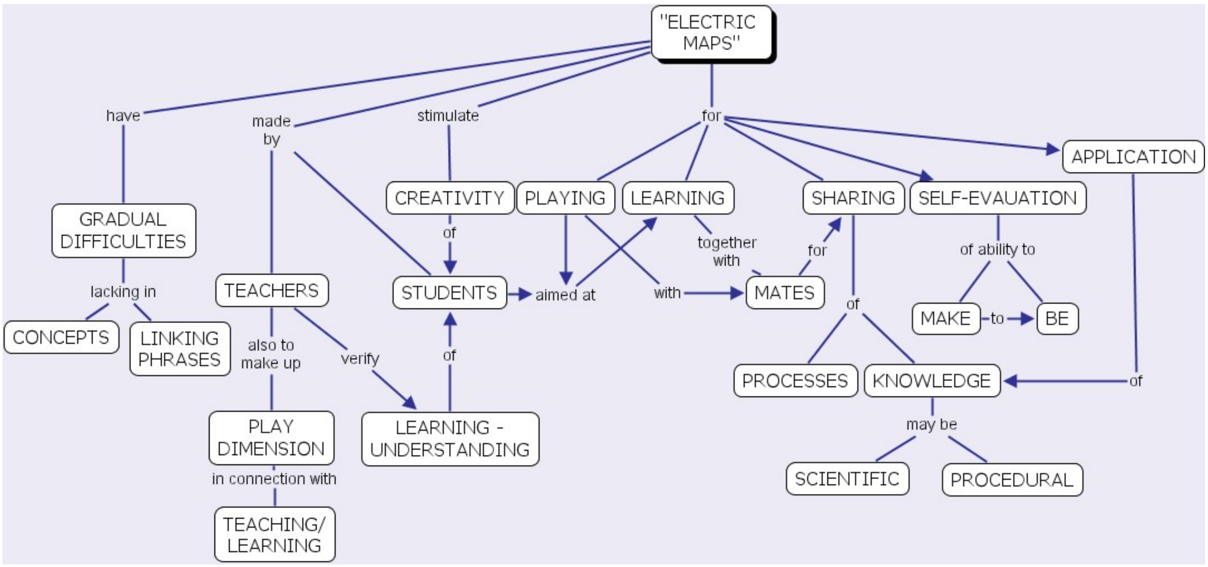

Figure 5. Electric maps in Our Educational Context

4 Acknowledgements

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ARK.I.NET, A GENERAL PURPOSE ENVIRONMENT TO SUPPORT THE COLLABORATIVE CONSTRUCTION OF KNOWLEDGE

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Abstract. ARK.I.NET, Architectural Knowledge in the NET, is a general purpose learning environment, which enables a group of users to construct knowledge in collaboration. ARK.I.NET's building blocks are concepts, themes and relations. The environment has been designed to foster the collaborative dimension in knowledge construction. Concepts can be defined in multiple ways; themes are set forth by grouping concepts from different users; and concept maps are built collaboratively, relating concept definitions and themes. It has been applied for the first time in a Ph.D. course, the interdisciplinary approach and constructivist methodology of which made it particularly suitable to unfold the pedagogical potential of the system.

1 Introduction

Since the academic course 1999-2000, in the course SDR: Sistemas de Representación we have been applying concept mapping tools in a collaborative scenario. These tools are part of a comprehensive web-based learning environment developed by the pedagogic research group ARC Arquitectura i Enginyeria La Salle especially for this course (http://www.salleurl.edu/sdr/info). In this environment, students analyze manifestoes of modern art and architecture, creating a vocabulary of critical concepts and collectively constructing a concept map which embodies the collective knowledge generated by the class (Madrazo et al. 2002).

This experience with concept maps convinced us of their pedagogic value, and motivated us to create a more comprehensive environment to support collaborative construction of concept maps, we named it ARK.I.NET, Architectural Knowledge in the Net. The goal was to provide a comprehensive tool that would facilitate the construction of knowledge to a group of students. The focus would be placed on the structuring of knowledge, in its architecture, and not so much on a specific subject matter (e.g. art, literature). From the technical standpoint, the goal was to enhance the capacities of the previous tool, building a stand-alone application, which would be platform independent and accessible through the web.

2 ARK.I.NET: Components

ARK.I.NET is a learning environment, which enables a group of users to participate in a collaborative process of knowledge construction, using concept map tools.

The architecture of the system is composed of three elements: concepts, themes and relations:

1- CONCEPT, a set of definitions identified by a name. A concept definition is the smallest block, from which other elements are formed.

$$C_n\ [D_1,\ldots,D_m]$$

2- THEME, a set of concept definitions that make a conceptual domain.

$$T_n\ [C_iD_j]$$

3- RELATION, a link between two concept definitions. A concept map is the result of the manifold relationships amongst concept definitions created by the users of the system.

$$R_n\ [C_iD_j\text{-}C_iD_j]$$

In Novak's *Learning How To Learn*, a concept is defined in the following terms: "We define *concept* as a regularity in events or objects designated by some label" (Novak, 1984, p.4). Novak's concept definition focuses on the denotative dimension of language: concepts as labels designating objects, or properties of objects. In ARK.I.NET, on the other hand, the connotative dimension of language is mostly stressed: concepts are not mapped to objects, but rather they are endowed with meanings along the process of knowledge construction.

These three elements -concepts, themes, and relations- are the building blocks for constructing knowledge collaboratively. The construction follows an ordered sequence, moving from the simplest element -a concept definition- to the most complex one -a concept map, made up of relations and intertwined themes. This notwithstanding, there are alternative ways to put together the three basic elements. For example, it is possible to introduce a new concept while navigating across the concept map. The different possibilities to use the three basic components in the construction of knowledge are represented in Figure 1. In (a) a theme is created from existing concepts; in (b) a relation is established between two existing concepts; and in (c) a new concept is created in the process of forming a relation.

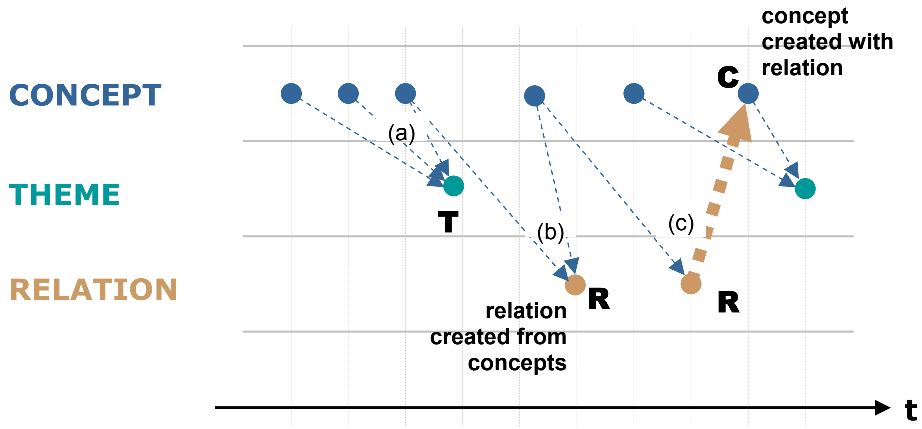

Figure 1. Concepts can be created before themes or relations or, they can be created at the same time.

3 ARK.I.NET: Structure of the System

This threefold structure, based on concepts, themes and relations, is reflected in the design of the interface. It is composed of three modes: CONCEPT mode, THEME mode and RELATION mode. Besides, there is a SYSTEM mode which informs about the activity of the system.

3.1 CONCEPT Mode

In the CONCEPT mode, users collaboratively create the smallest elements -the concepts- with which themes or relations are to be created. Each concept is made up of a set of concept definitions, numbered by an index (e.g. ‘Form[1]’, ‘Form[2]’,.....make the concept ‘Form’). The attributes of a concept include: name, definition, topic, source, user and date. This would be an example of the CONCEPT FORM, as defined by students using ARK.I.NET in a Ph.D. course dedicated to oppose the thinking of architects to the thinking of philosophers (see Section 5 below):

Form[1]: “Appearance and manner to order a thought”.
Form[2]: “What does not exist by itself”.
Form[5]: “The language of things”.

These definitions are not meant to be taken from a dictionary. Rather, they are notions of form derived from lectures, and expressed with students’ own words.

The CONCEPT mode has two distinct interfaces: 1. to list all concepts 2. to know about a selected concept in-depth. The table to list concepts is built block by block, as the user selects some of the attributes of a concept (Figure 2). For instance, by selecting the attribute ‘user’, the table would only show the concepts introduced by the selected user. If we then select the attribute ‘topic’, it would append to the previous block the list with the concepts sharing the selected topic. This way, the user can build a table at will, each block made up of a subset of the vocabulary.

Concepts can be created inserting a new entry on the same table. They can be edited or deleted, providing that they have not been included in a theme or a relation by another user. Also, it is possible to move across modes, selecting a concept and taking it to the mode THEME or to the mode RELATION to construct a higher order entity with it.

To be able to get a thorough information about a concept, this has to be selected in the table and carried on to the second interface (Figure 3). In this interface, it is possible to read all of the definitions of the selected concept, or, alternatively, list all of the themes and relations where a selected concept definition is intervening. This way, we can quickly get an overview of the relevance that a particular concept is acquiring in the collective knowledge construction process. It also serves as a navigation map to move quickly to the other two modes, by clicking on the name of the theme or the relation which a concept definition is part of.

Figure 2. CONCEPT mode. Table to visualize the vocabulary.

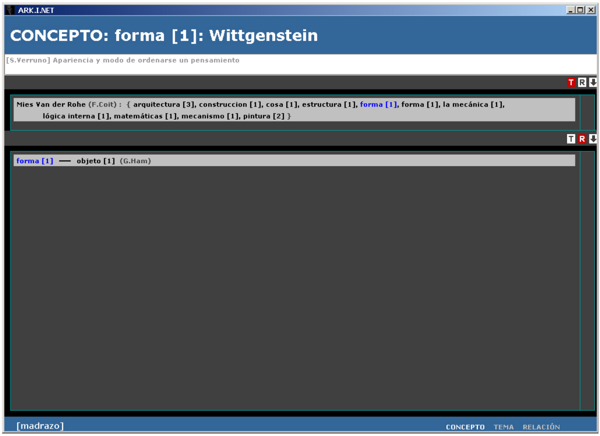

Figure 3. CONCEPT mode. View of single concept.

3.2 THEME Mode

In the THEME mode, concept definitions are grouped to create higher order entities named themes. The purpose of this mode is to create new conceptual domains by grouping concept definitions. These domains provide a context where concepts acquire a more concrete meaning. Somehow, a theme can be understood as a concept map with no explicit relations among them.

To create a theme, the concept definitions are selected from the existing vocabulary and dragged onto the main window (Figure 4). The vocabulary, which appears on the left column, can be filtered by attribute to reduce the number of entries a user might want to work with. Once the concepts are in the working area, their attributes can be edited (spatial position, color, and font). With these attributes concepts get more expressiveness, making them more intelligible and meaningful to others (Wallace et al., 1998). The theme, that is to say, the context which gives particular meaning to the selected concepts, is defined by the user with a short text. Also, it is necessary to describe the relationship that each selected concept holds with the suggested theme.

In order to make it possible for the user to work on the creation of a theme during several sessions, the work-in-progress can be saved in an individual working space (I-Workspace) to be published later (e.g. made available to all other users).

If during the process of creating a theme, a user realizes that it is necessary to define a concept which is not in the vocabulary, it is not necessary to move to the CONCEPT mode to do it. The CONCEPT definition procedure can be invoked without leaving the THEME mode. This way, these two modes -CONCEPT and THEME- become interwoven during the process of knowledge construction.

Already defined themes can be visualized in the same interface, after switching to the visualization sub-mode. Then, the names of existing themes are listed on the vertical column. To reduce the number of elements in the list, themes can be filtered by user name or by the concepts that they contain. A particularly powerful feature, enables the user to fix a concept that will serve as a vector traversing a set of themes created by several users, all of them sharing the selected concept (Figure 5). To move from one theme to another along this vector, it is enough to drag the cursor on a slider. As we move the cursor, the themes appear and disappear, merging one with the other, suggesting new ways to group concepts (e.g. new themes). Thus, moving from one theme to another becomes an opportunity for knowledge discovery in a collaborative scenario. At any moment during this navigation through the existing themes, a user can save the information being displayed on the screen, to be recovered later.

To have an overview of all existing themes, there is a table that can be built by the user, in much the same way as the table in the CONCEPT mode. Blocks of themes are displayed after selecting one of its attributes (name, description, concepts, user and date). A theme can be selected from this list to create a new theme out of it. From the point of view of collaborative thinking, this is a particularly powerful feature, since it allows users to create a chain of themes.

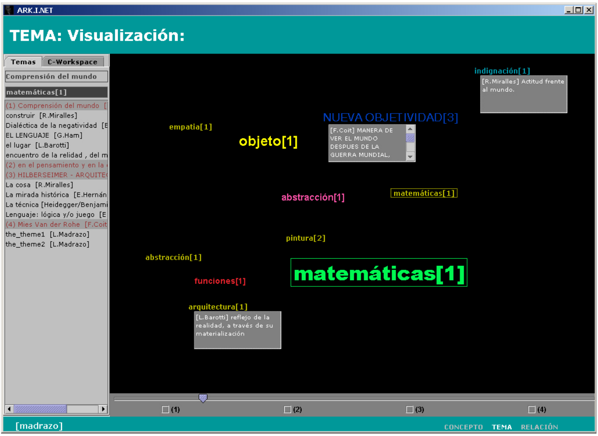

Figure 4. THEME mode. Interface to create/visualize a theme.

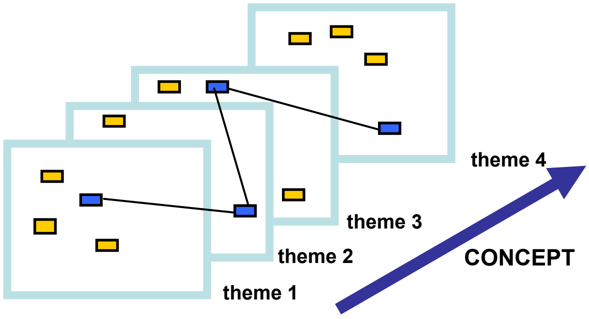

Figure 5. THEME mode. Navigation through the themes.

3.3 RELATION Mode

In ARK.I.NET, a RELATION is a description of the link between two concept definitions, as described by the user. There is no distinction between concept words and non-concept words, as in Novak's concept maps, where the first ones are thought of as concept labels and the second as links.

A user can establish any number of relationships between any pair of concept definitions. All these relationships are recorded by the system, and then represented as a concept map. The visualization of the concept map becomes a construction process: as the user explores paths in the net of concepts, the structure of connected concepts is formed (Figure 6).

In ARK.I.NET, relations between two concepts can be dyadic or triadic (Figure 7). In the dyadic mode, the link between two concepts is described by means of a text. The triadic structure evokes Pierce's semantic triangle, where the *representamen* and the *object* would lie at the bottom, and the *interpretant* at the vertex (see Sowas' *Knowledge Representation* for a discussion on dyadic and triadic structures in conceptual graphs). However, in our triadic structure, a sign is not related to the object -as in Pierce- but rather there are two *representamen* (e.g. two concept definitions) at the base of the triangle. In this context, the third concept sets up some limits to the universe of meanings that the relations between the other two might bring about. Such triadic structure can be understood as a reduced theme, made up of only two concepts, the third one being the label for the theme.

As in the THEME mode, in the RELATION mode there are also three kinds of interface: 1. to create a relation 2. to visualize the existing relations as a concept map and 3. to list the existing relations.

The process to create a relation is very intuitive. In the corresponding interface concepts are selected and dragged onto the working area. Then, in order to establish a relation between two concept definitions, it is enough to pick and drag one node over the other. As a result, a line connecting the two nodes is displayed, and the user is prompted to explain the relation with a short text. In much the same way as with the mode THEME, the user has the option to save the relation in the individual working space (I-Workspace) to be published at a later time.

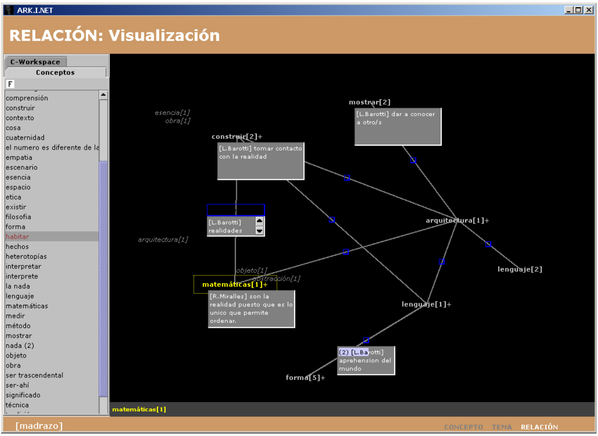

Figure 6. RELATION mode. Interface to creation relations.

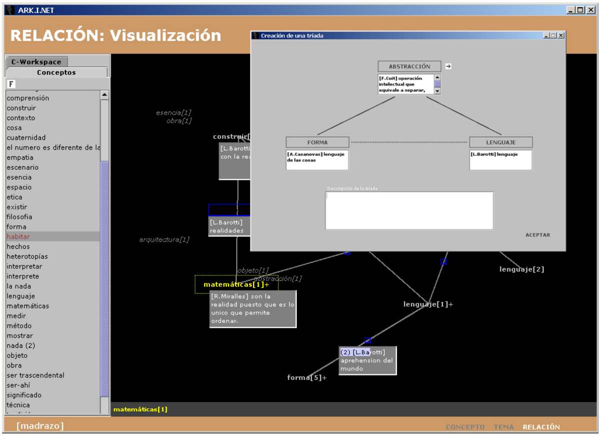

Figure 7. RELATION model. Triad connecting three concepts.

To visualize the network of existing relationships as a concept map, it is necessary to change to the visualization sub-mode. At the outset, a concept is selected from the list on the left column and dragged onto the working area. This concept becomes the focus node of the portion of the concept map to be displayed. The '+' sign appended to the concept indicates that there are other concepts related to this. As we click on a node, the related concepts are displayed. The process of opening up nodes can be repeated up to three times for a given portion of the map. Then, to continue navigating further, the focus node needs to be replaced. All focus nodes selected in one session are recorded in a history line, so that the user can recover an area of the map by clicking on one of the visited nodes.

Relationships between concepts are visualized as lines with a node at the center. Only one relation between two pairs of concepts is displayed, although there might be many relations established between the two. If this is the case, a '+' sign appears in the node placed at the middle of the connecting line. Then, the user can select one of the existing relationships to be displayed.

While users navigate through the concept map, the process of building relationships continues. For instance, a user can add a node to the currently displayed portion of the concept map, simply dragging a new concept to the working area. Also, a user can create triadic relationships by adding a third concept to an existing relation, directly on the concept map. If in the course of navigating through the map a user recognizes the need to create a new concept, the CONCEPT creation procedure can be called up within the RELATION mode.

As concepts in the map might be also part of a theme, it is possible to display the set of concepts that share a theme with the selected node. After clicking on a node, a myriad of concepts appear around it, suggesting possible intersections between the group of concepts making a theme and those making the concept map.

Particularly important, for the collaborative construction of knowledge, is to switch to a collaborative working mode, which enables the user to store the current portion of the concept map, label it and comment it. This way, other users can later retrieve these reflections as they navigate through the concept map. Also, these partial views of the map are useful to be shown and explained in the class discussions.

Consistently with the other two modes, there is also an interface where all existing relations are listed as a table constructed by the user. The entries can be edited by the owner, providing that no other user has made use of them. Also, as in the CONCEPT and THEME tables, an item from the list can be selected to be modified or to create a new one from it; in this case, a new relation.

3.4 SYSTEM Mode

Besides the three structural modes, there is a fourth one for the user to get easily oriented throughout the flow of information produced by the system. As the user logs in, a screen shows the activity of the system, at the individual and collective levels, week by week (Figure 8). The area on the left shows the records of the actions done by the user (e.g. defining a concept, creating a theme or relation,....). The right side is divided into three rows, each one displaying the activities of a user concerning concepts, themes and relations, for each week during the system activity.

With this mode, the user gets a quick overview of the system activity: which concepts are being defined, which themes are being proposed, and which relationships are being established. By clicking on one of the items, we move to the corresponding mode, carrying with us the selected item. For instance, if we are interested in a relation that a user has established between two concepts, by clicking on the relation this will be visualized in the RELATION mode.

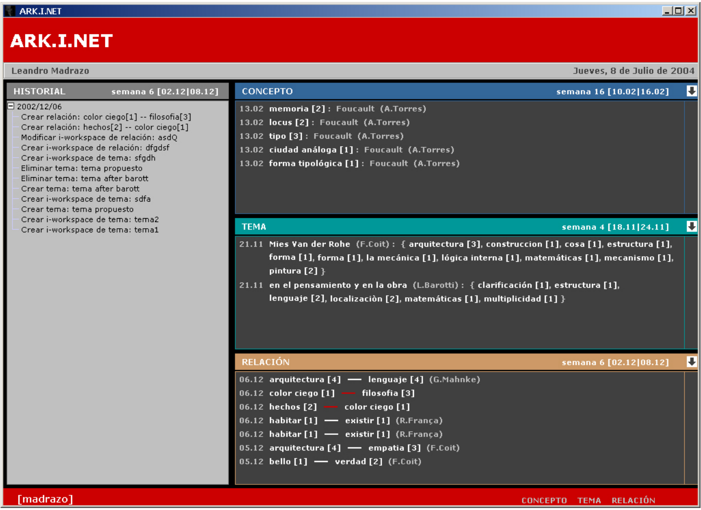

Figure 8. SYSTEM mode.

4 Concept Maps and Knowledge Maps

Distinctions between concept map, cognitive map, semantic network and knowledge map are sometimes hard to establish. According to Novak, "Concept maps are intended to represent meaningful relationships between concepts in the form of propositions" (Novak, 1984, p.15). As ARK.I.NET is not meant to represent propositions made up of concept words connected by non-concept words, it might not be called a concept map. Concept maps that are meant to represent an individual's knowledge are referred to as cognitive maps (Sherratt et al., 1990). Since ARK.I.NET is a collaboratively constructed concept map, it might not necessarily be a cognitive map, although users can see their thinking structure represented in it, to some extent. A semantic network, according to Sowa, is "a graphic notation for representing knowledge in patterns of interconnected nodes and arcs....a declarative graphic representation that can be used either to represent knowledge or to support automated systems for reasoning about knowledge". ARK.I.NET does not have the inner declarative logic of such semantic networks. Finally, the term knowledge map is sometimes used for concept maps which help a community of learners to derive knowledge from them in collaboration (Lambiotte et al. 1989). In this sense, the term knowledge map would be the most adequate to describe ARK.I.NET. Nevertheless, we have used concept map throughout the whole text, because of its generality.

5 Pedagogic Application

ARK.I.NET provides a 'neutral', language-based structure that allows a group of users to construct knowledge using linguistic blocks, regardless of the subject matter at stake. In order to test the validity of the tool -from the conceptual and the functional point of view- we used it in a Ph.D. course named PENSAMIENTO:FORMA (http://www.salleurl.edu/arq/plaestudis/doctorat), in the academic year 2002-03.

The purpose of this course was to weave strands between architecture and philosophy. The series of lectures were structured into four blocks, each one dedicated to confront the ideas of a philosopher with the works and thoughts of an architect: Wittgenstein (philosopher) vs. Wittgenstein (architect); Heidegger vs. Mies; Foucault vs. Rossi; and Gadamer vs. Koolhaas. Each block consisted of three lectures, given by known specialists on each author.

Students were asked to summarize each lecture in a few concepts, to be introduced in ARK.I.NET. At the end of each block of lectures, they were asked to build themes, grouping concepts. The themes proposed were the contexts where concepts would be endowed with concrete meaning. These themes were then presented in the classroom, using the interfaces of the THEME mode. As a final step, students were asked to create pairs of relationships between concepts, which then would be visualized as a concept map in the RELATION mode.

In this context, the concept map became both a representation of the collective knowledge gathered by the group and a generator of new knowledge. However, eliciting knowledge embedded in a concept map which has been collaboratively created marks the beginning of a complex social and intellectual process, rather than the endpoint of a knowledge construction process. As McAleese, has contended: "In the construction of conceptual maps learners will come to negotiate and modify what it is that they appear to know in terms of what is known". (McAleese, 2000). As a matter of fact, in the process of constructing a map with ARK.I.NET, the learner's own knowledge is confronted to the collective knowledge embedded in the map.

Our assumption was, that the isolated blocks of knowledge that students derived from each lecture would give rise to a collaborative construction of a subject-matter which was not laid out in any form (book, syllabus) before the course started. This way, a complete integration of content, methods and tools would be achieved. At the outset, it seemed a sound pedagogic strategy, backed by the successful experience of using similar but simpler environments in our undergraduate courses. However, the results from this first application were not as encouraging as we had expected. Participating in a collaborative process of knowledge construction -such as the one supported by ARK.I.NET- means a high intellectual level for all participants. Summarizing lectures in philosophy and architectural theory in a few concepts, describing them in a meaningful and suggestive manner, and being creative discovering relationships, demands a linguistic and cultural competence which not all students -even at the postgraduate level- possess. Moreover, working with concept maps representations requires a metaknowledge capacity which cannot be taken for granted even in postgraduate education. Eliciting knowledge from a concept map, in a multidisciplinary context, is a big challenge for all participants, students and teachers. Also, we must keep in mind that behind some of these difficulties lie issues which are still a matter of research, including: construction of meaning through direct manipulation of conceptual maps; the role of conceptual maps in the eliciting/structuring of knowledge; and the process of finding/discovering meaning through navigation in semantic spaces (Landauer et al., 2000; Gärdenfors, 2000).

6 Summary

We have developed a general purpose system, which can support collaborative construction of knowledge using language. This construction is based on three basic elements: concepts, themes and relations. This threefold structure is embedded in the user interface and in the modes of operating with the system. In order to have a pedagogic relevance, it is necessary to create the appropriate learning scenarios, where the potential of the system can be unfolded.

7 Acknowledgments

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LOS MAPAS COGNITIVOS, ELABORADOS A PARTIR DEL CUESTIONARIO INPECIP, EN LA EVOLUCIÓN (1993-2002) DE LAS CONCEPCIONES DE UNA PROFESORA DE CIENCIAS DE SECUNDARIA

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Resumen: En la comunicación describimos la construcción de mapas cognitivos a partir del cuestionario INPECIP (Inventario de Creencias Pedagógicas y Científicas de Profesores), diseñado y validado por Porlán et al. (1997) como instrumento para analizar las concepciones del profesorado de ciencias experimentales. Posteriormente aplicamos los mapas en una investigación longitudinal con una profesora de secundaria de biología, en dos momentos distintos de su vida profesional, para determinar los factores que favorecen u obstaculizan el cambio didáctico de sus concepciones sobre la naturaleza de la ciencia y sobre la enseñanza y aprendizaje de la misma.

1 Introducción

La comprensión de los cambios didácticos del profesorado y de los factores que los estimulan u obstaculizan es actualmente uno de los temas más relevantes de la agenda de la investigación educativa (Mellado, 2003) y un elemento esencial para planificar y llevar a cabo programas de formación inicial y permanente del profesorado, si queremos que éstos programas tengan una incidencia real en la mejora del proceso de enseñanza/aprendizaje en las aulas. Desde la década de los ochenta se ha producido un considerable aumento de las investigaciones que tienen como protagonistas al profesorado de ciencias (Tobin, Tippins y Gallard, 1994). Tanto las investigaciones de fundamento constructivista (Furió y Carnicer, 2002; Gil, 1993) como las que inciden en la metacognición, señalan la necesidad de potenciar la reflexión del profesorado para posibilitar la autorregulación y el control de los cambios (Gunstone *et al.*, 1993; Copello y Sanmartí, 2001). La reflexión también es importante en las orientaciones que proponen una evolución gradual de los modelos didácticos del profesorado (Porlán y Rivero, 1998).

En este trabajo describimos una parte de una investigación longitudinal con una profesora de secundaria de biología, para determinar los cambios de sus concepciones sobre la naturaleza de la ciencia y sobre la enseñanza y aprendizaje de la misma. Aunque se ha utilizado una combinación de cuestionarios y entrevistas, en la comunicación nos centraremos en el análisis de los cambio por medio de los mapas cognitivos construidos a partir del cuestionario INPECIP.

El cuestionario se ha asociado habitualmente a métodos cuantitativos y a procedimientos estadísticos de investigación, en cambio la entrevista es un procedimiento de recogida de datos habitualmente asociado a metodologías de análisis cualitativas. Hoy tanto uno como otro procedimiento se utilizan cuantitativa o cualitativamente según la naturaleza del problema investigado. La utilización de los mapas cognitivos, como procedimiento de análisis de los datos obtenidos de los cuestionarios, permiten a cualquier observador externo replicar con facilidad el análisis a través de los datos, lo que refuerza la fiabilidad de la investigación.

En otros trabajos (Mellado *et al*, 2002) hemos analizado la utilización de los mapas conceptuales de Novak y colaboradores, ampliamente validados en numerosos trabajos (González, 1992; Novak, 1988 y 1998) tanto con alumnos como con profesores, así como su evolución hacia los mapas cognitivos (Novak y Gowin, 1988). El mapa conceptual tendría una estructura lógica aceptada socialmente por los expertos del tema. En cambio el mapa cognitivo tendría una estructura más psicológica y formaría una representación idiosincrásica personal.

Los mapas cognitivos relacionan, de una forma parcialmente jerarquizada, unidades de información con un sentido más amplio que los conceptos utilizados en los mapas conceptuales. La representación por medio de mapas cognitivos permite una visión global y no fragmentada de las concepciones de cada profesor sobre distintos aspectos. Los mapas cognitivos de los profesores pueden ser construidos por ellos mismos o por un investigador externo a partir de los datos obtenidos de los profesores (Mellado, 1998; Mellado *et al.*, 2002).

2 Construcción de mapas cognitivos sobre las concepciones del profesorado a partir del cuestionario INPECIP

Cualquier cuestionario cuyas diferentes categorías se correspondan con modelos definidos y contrapuestos pueden analizarse por medio de mapas cognitivos. En particular los cuestionarios tipo Likert, en los que los sujetos muestran su acuerdo o desacuerdo con las declaraciones de los ítem, pueden adaptarse a esta técnica de análisis. Sin embargo los resultados son mucho mejores cuando el cuestionario se ha elaborado en función de su posterior análisis por mapas cognitivos.

El cuestionario INPECIP (Inventario de Creencias Pedagógicas y Científicas de Profesores), diseñado y validado por Porlán *et al.* (1997) en la Universidad de Sevilla para determinar las concepciones didácticas y epistemológicas del profesorado de ciencias experimentales, no está especialmente diseñado para ser analizado por mapas cognitivos, por lo que nos puede servir como ejemplo de adaptación posterior. Consta de 56 items, distribuidos inicialmente por Porlán en cuatro categorías: modelo didáctico personal (2, 3, 12, 13, 16, 17, 18, 20, 26, 29, 30, 31, 34 y 53), imagen de la ciencia (4, 11, 21, 22, 23, 28, 38, 39, 40, 42, 44, 47, 51 y 55), teoría del aprendizaje (5, 8, 14, 19, 24, 27, 32, 33, 35, 41, 46, 48, 50, 54) y metodología de enseñanza de las ciencias (1, 6, 7, 9, 10, 15, 25, 36, 37, 43, 45, 49, 52, 56).

Las proposiciones de los ítem se corresponden en cada categoría con dos modelos extremos y contrapuestos, el primero más tradicional y el segundo más en sintonía con las actuales concepciones didácticas y epistemológicas, que denominaremos modelo constructivista.

Sin embargo para el análisis se realizaron algunas modificaciones. En primer lugar no se analizaron los ítem 3, 12, 18, 29 y 53 que tratan del conceptos generales sobre la didáctica, menos relevantes para el profesorado de primaria y secundaria y por tanto para el objetivo de nuestra investigación. El resto de los ítem se agruparon en tres categorías: "imagen de la ciencia", "aprendizaje de las ciencias", coincidentes con las iniciales de Porlán, y "enseñanza de las ciencias", que incluye los ítem de esta categoría más los que inicialmente Porlán incluía en la categoría "modelo didáctico personal", que hemos integrado en aquella.

Para la construcción de los mapas cognitivos generales de cada categoría se comienzan seleccionado todas las proposiciones del modelo tradicional y las opuestas del modelo constructivista. Posteriormente se enlazan las proposiciones de los ítem de las más generales e inclusoras a las más particulares, formando el mapa cognitivo del modelo a de la categoría, realizado con una técnica análoga a la que utiliza Novak para los conceptos. En cada mapa es necesario mantener la independencia de las declaraciones, aunque tengan el mismo significado, aún a costa de hacer el mapa repetitivo, pues puede ocurrir que las respuestas de los sujetos sean diferentes y contradictorias, hecho que hay que reflejar.

Como el cuestionario INPECIP no ha sido expresamente diseñado para este tipo de análisis, en el mapa cognitivo realizamos simplificaciones en la redacción de las proposiciones para que el mapa cognitivo sea más sencillo. Cuando una de las proposiciones del cuestionario expresa simultáneamente más de un concepto podemos dividirla en dos en el mapa, aunque esto dificulta su aplicación. La construcción de los mapas supone una evaluación del cuestionario, pues fácilmente se detectan las contradicciones del mismo, o si un ítem no está adecuadamente adscrito.

En el caso del INPECIP en la categoría imagen de la ciencia los autores del cuestionario asignan al modelo tradicional los ítem 4, 21, 22, 40, 42, 44 y 47 y al modelo más acorde con las orientaciones actualmente defendidas por la nueva filosofía de la ciencia, o constructivista, los ítem 11, 23, 28, 38, 39, 51 y 55:

4. Las teorías científicas obtenidas al final de un proceso metodológico riguroso, son un reflejo cierto de la realidad.
11. En la observación de la realidad es imposible evitar un cierto grado de deformación que introduce el observador.
21. El observador científico no debe actuar bajo la influencia de teorías previas sobre el programa investigado.
22. Toda investigación científica comienza por la observación sistemática del fenómeno que se estudia.
28. El pensamiento de los seres humanos está condicionado por aspectos subjetivos y emocionales.
38. El investigador siempre está condicionado, en su actividad, por la hipótesis que intuye acerca del problema investigado.
39. El conocimiento científico se genera gracias a la capacidad que tenemos los seres humanos para plantearnos problemas e imaginar posibles soluciones a los mismos.
40. La eficacia y la objetividad del trabajo científico estriba en seguir fielmente las fases ordenadas del método científico: observación, hipótesis, experimentación y elaboración de teorías.

42. La metodología científica garantiza totalmente la objetividad en el estudio de la realidad.
44. A través del experimento, el investigador comprueba si su hipótesis de trabajo es verdadera o falsa.
47. La Ciencia ha evolucionado históricamente mediante la acumulación sucesiva de las teorías verdaderas.
51. Las hipótesis dirigen el proceso de investigación científica.
55. La experimentación se utiliza en ciertos tipos de investigación científica, mientras que en otros no.

En el mapa tradicional del cuestionario sobre la imagen de la ciencia (figura 1), incluiríamos las proposiciones del modelo tradicional (4, 21, 22, 40, 42, 44 y 47) y también las opuestas del modelo constructivista (no 11, no 23, no 28, no 38, no 39, no 51 y no 55).

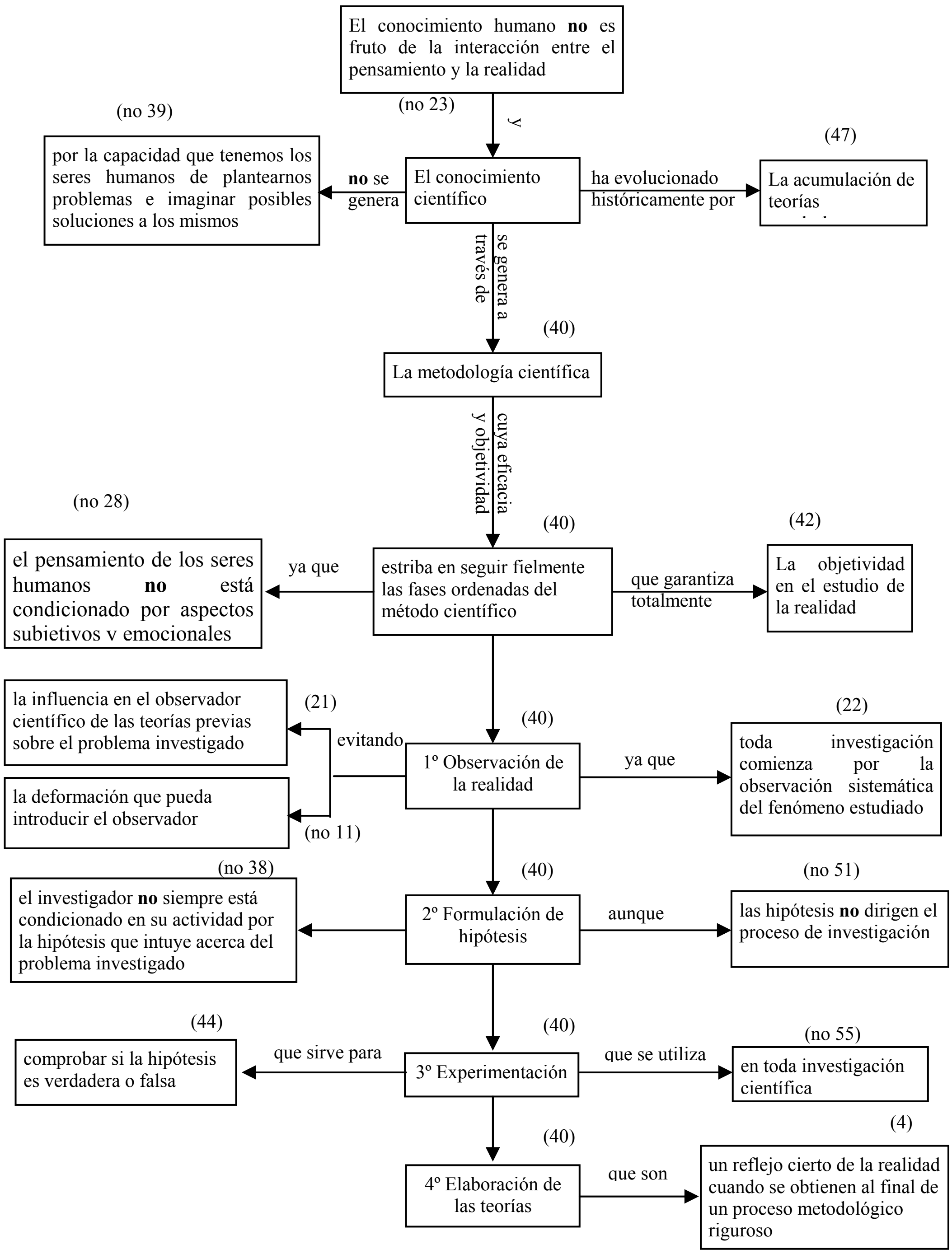

Figura 1. Mapa general del cuestionario INPECIP con la imagen tradicional de la ciencia.

En la construcción del mapa constructivista del cuestionario sobre la imagen de la ciencia (figura 2) incluiríamos las proposiciones del modelo constructivista (11, 23, 28, 38, 39, 51 y 55) y las opuestas del modelo tradicional (no 4, no 21, no 22, no 40, no 42, no 44 y no 47).

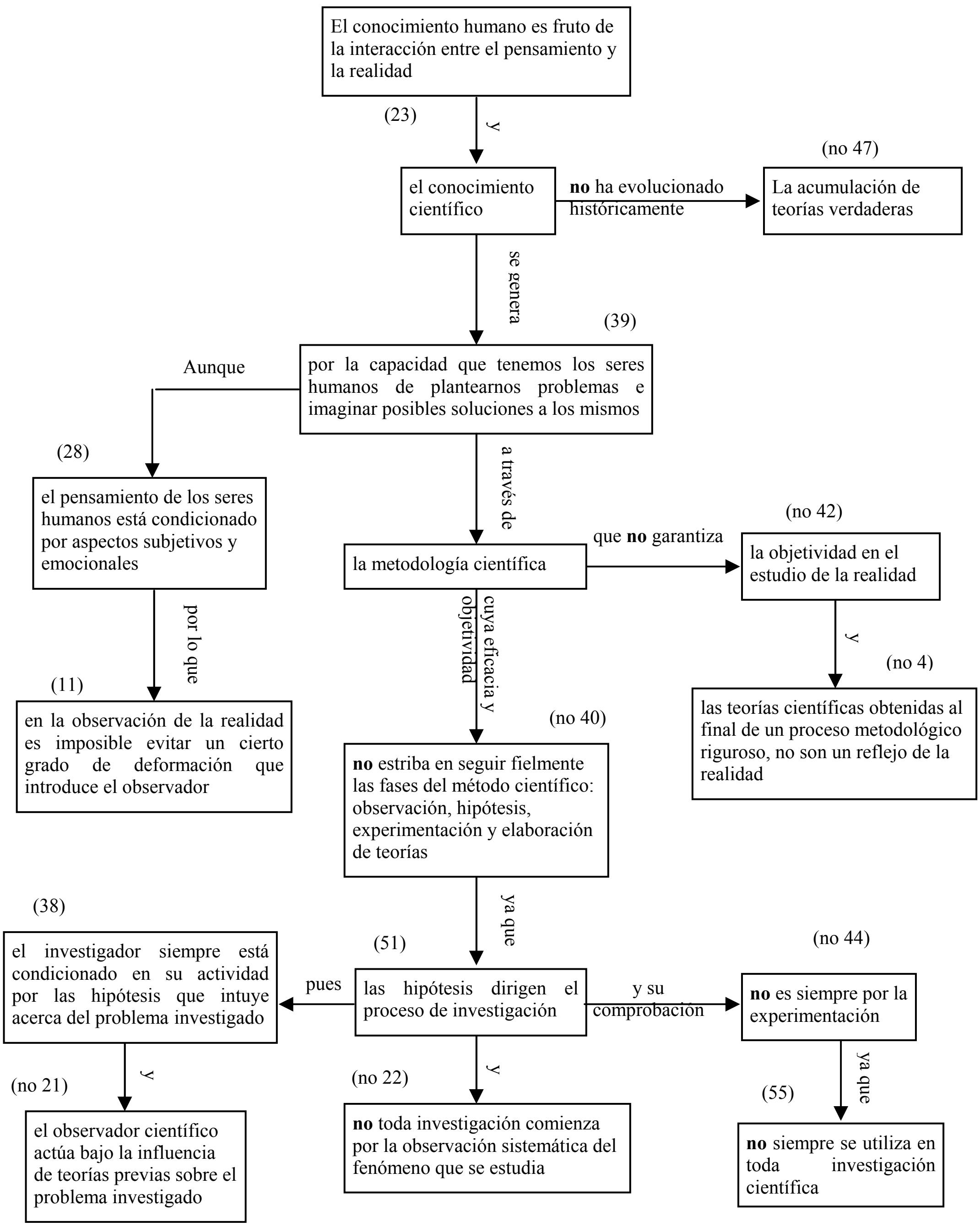

Figura 2. Mapa general del cuestionario INPECIP sobre la imagen constructivista de la ciencia.

Del mismo modo procederíamos para la construcción de los mapas del INPECIP correspondientes a las categoría "aprendizaje de las ciencias" y “enseñanza de las ciencias”.

3 Mapas cognitivos de la profesora de biología de secundaria

A continuación describimos el proceso de construcción de los mapas cognitivos de una profesora de biología de secundaria, con 15 años de experiencia, que contestó al cuestionario INPECIP en los años 1993 y 2002. Para construir los mapas personales de esta profesora, se adscriben sus respuestas al cuestionario al mapa correspondiente, en cada una de las tres categorías, eliminando las declaraciones no contestadas. Para el dibujo final de los mapas cognitivos personales se eliminan los huecos de modo que haya un enlace entre las declaraciones resultantes. En 1993 en la categoría imagen de la ciencia mostró su acuerdo con los ítem 4, 21, 22, 40, 42, 44 correspondiente a la imagen tradicional y su desacuerdo con el ítem 55. Esto da el mapa cognitivo de la figura 3.

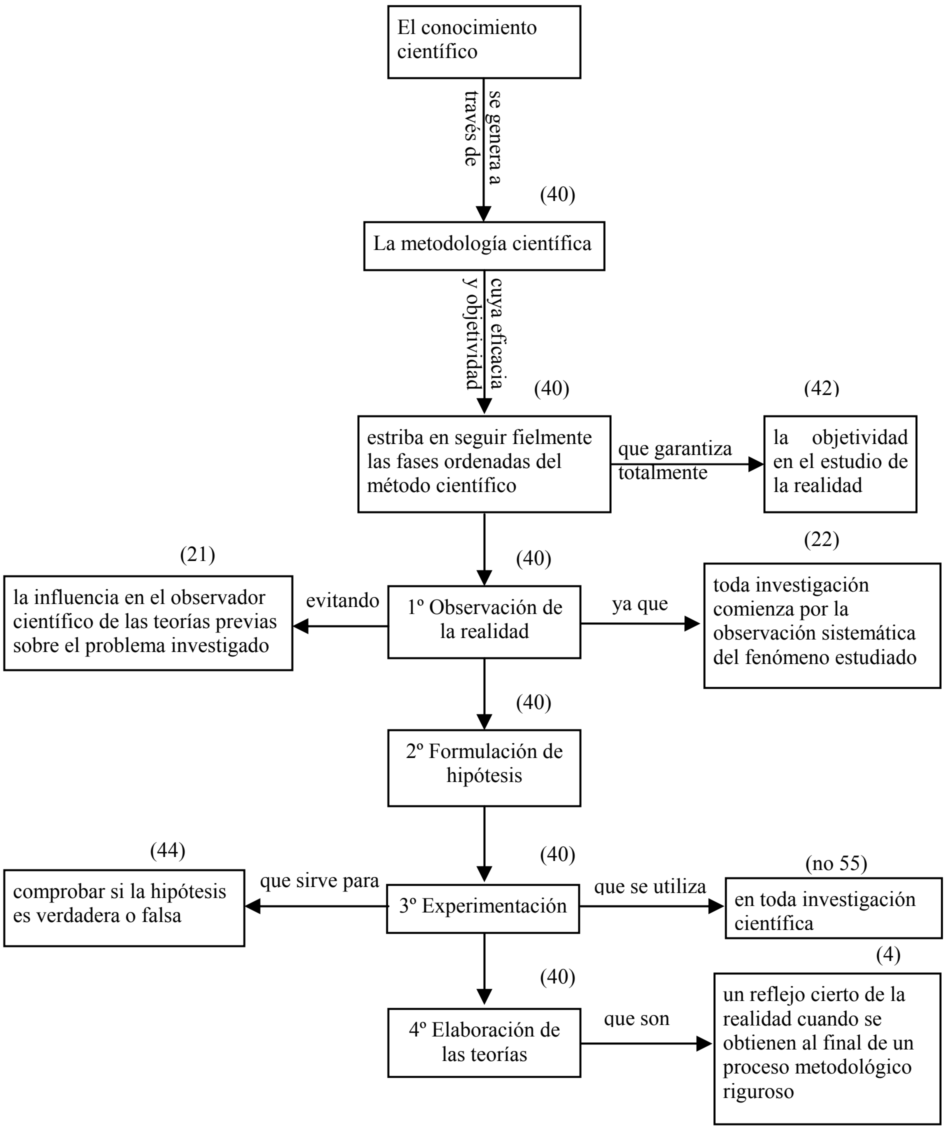

Figura 3. Mapa Cognitivo tradicional de la profesora sobre la imagen de la ciencia en 1993.

En 1993 mostró su acuerdo con los ítem 11, 28, 39 y 51 y su desacuerdo con el 47, lo que nos da el mapa de la figura 4.

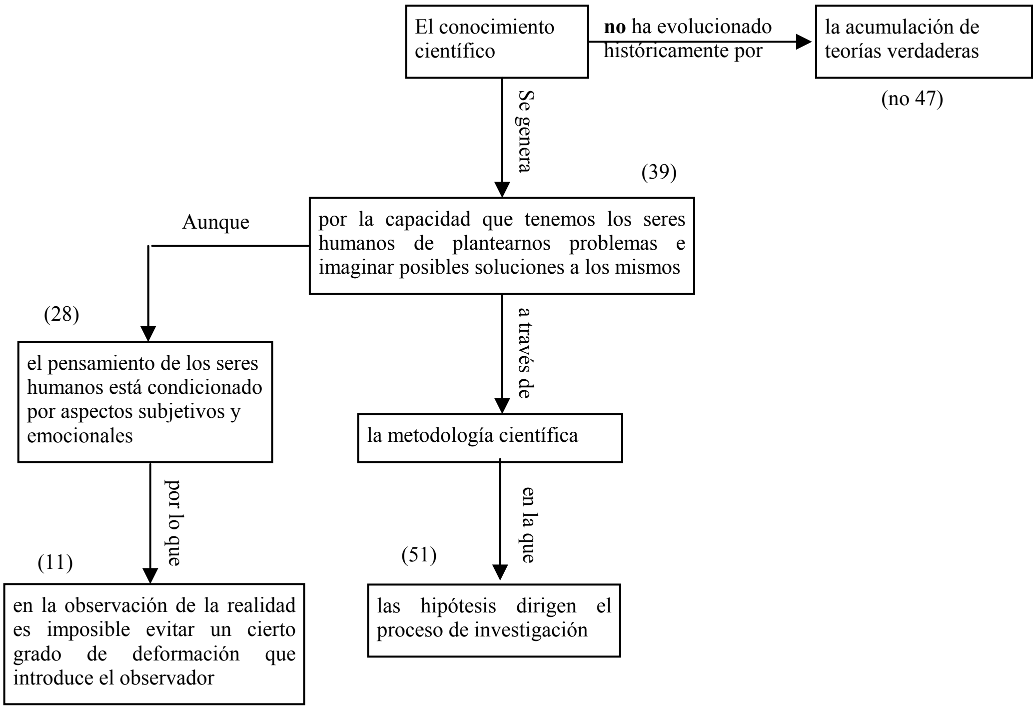

Figura 4. Mapa Cognitivo constructivista de la profesora sobre la imagen de la ciencia en 1993

Al visualizar ambos mapas, la profesora analizada puede obtener una imagen gráfica global e interrelacionada de su concepción sobre la naturaleza del conocimiento científico, la cual en el año 1993 tiene un marcada tendencia positivista.

En el año 2002 la profesora mostró su acuerdo con los ítem 11, 28, 38, 39, 51 y 55 y su desacuerdo con los ítem 4, 21, 42 y 47. Estas respuestas están todas asociadas al modelo constructivista y determinan el mapa de la figura 5. En este año ninguna de las respuestas de la profesora estarían asociadas a la concepción tradicional. En los nueve años transcurridos se observa una notable evolución de esta profesora del modelo positivista hacia otro más próximo a la nueva filosofía de la ciencia.

De forma análoga procederíamos para los mapas sobre el aprendizaje de las ciencias y la enseñanza de las ciencias.

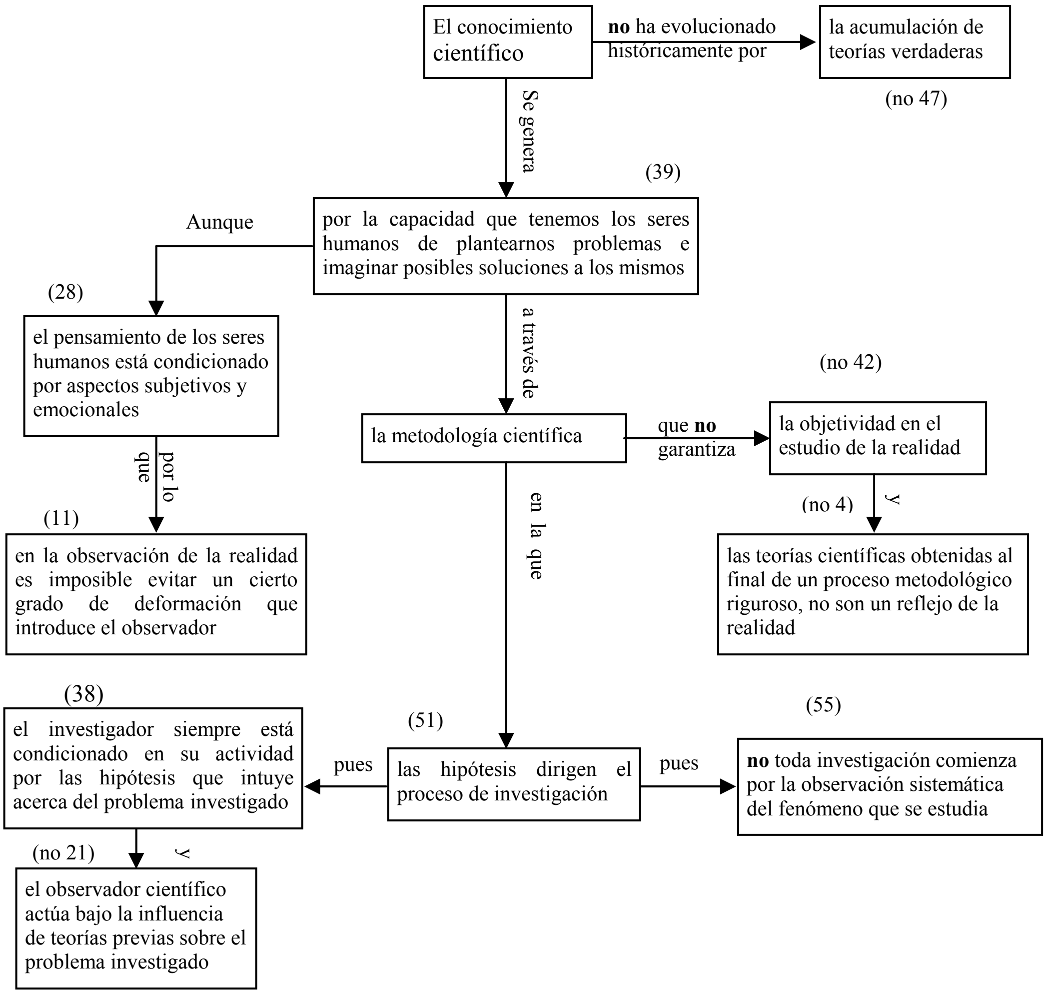

Figura 5. Mapa Cognitivo constructivista de la profesora sobre la imagen de la ciencia en 2002

4 Conclusiones

De las numerosas reflexiones que hemos realizado sobre la utilización práctica del análisis de datos por medio de los mapas cognitivos en las investigaciones con el profesorado de ciencias experimentales, destacamos las siguientes conclusiones:

- Lejos de las polémicas iniciales que enfrentaban a los métodos cuantitativos y a los cualitativos en la investigación educativa, consideramos que actualmente debe primar el pluralismo metodológico, supeditándose la metodología a la naturaleza del problema de investigación que se plantee en cada caso.
- La utilización de los mapas cognitivos nos parece un buen procedimiento gráfico de análisis, para los datos obtenidos de los cuestionarios dicotómicos. La representación por medio de mapas cognitivos da una visión global y no fragmentada de las concepciones de cada profesor, considerado individualmente, sobre los distintos aspectos analizados.
- El cuestionario INPECIP diseñado y validado por Porlán *et al.* (1997) en la Universidad de Sevilla para determinar las concepciones didácticas y epistemológicas del profesorado de ciencias experimentales, se ha mostrado como un buen instrumento para ser analizado por medio de mapas cognitivos, a pesar de no haber sido específicamente diseñado para ello.
- El análisis de la evolución de las concepciones, representadas por medio de los mapas cognitivos, por parte de la profesora participante en la investigación, favorece la reflexión y la metacognición, con lo que esta metodología es reconocida por ella misma como una herramienta de intervención en su desarrollo profesional.

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Concept Maps: Theory, Methodology, Technology
Proc. of the First Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

CONCEPT MAPS AND WAGON WHEELS: MERGING METHODS TO IMPROVE THE UNDERSTANDING OF TEAM DYNAMICS

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Abstract. The study of team performance using knowledge elicitation methods can result in the proliferation of large amounts of data. While methods such as the Wagon Wheel Method have been devised to facilitate knowledge elicitation, they often underspecify analysis protocols for dealing with large datasets. Moreover, the representation of the analysis poses challenges for transforming the knowledge gained during elicitation into applications. This paper explores the merging of the Wagon Wheel Method with Concept Mapping to enhance the study of team dynamics and performance. Recommendations for new elicitation, analysis, and representation techniques are offered using notional and real-world datasets. The resulting merged method can be useful for developing and presenting both overarching and intimate knowledge of teams.

1 Introduction

Knowledge elicitation about team dynamics hinges on an important principle: the knowledge elicitor's understanding of the team will be broader and deeper than that of any of the members of the team under study. A primary advantage of studying teams is to provide just this overarching and intimate look at the way teams operate in both effective and ineffective ways.

However, any serious study of team performance will result in an abundance of data. Methods of Cognitive Task Analysis have been developed to enable the elicitation of team dynamics, yet analysis methods are often underspecified, or complicated by the sheer volume of data (Klinger & Hahn, 2002; 2003). Even with a well-specified protocol for analysis, a challenge remains in conveying in a meaningful way the knowledge gained—that is, in moving from analysis to representation. This is particularly challenging if the purpose of conveying the knowledge is to inform an application of it, perhaps for organizational redesign, or developing training or information technology support systems. Static representations (e.g., organization charts) can often portray the breadth of understanding, but can be limited in the depth to which they can demonstrate what has been learned. Dynamic representations (e.g., process models), while enabling demonstration of the "way things work," can also be limited to presenting a singular view of the knowledge gained, even when animations are used.

What the "knowledge analyst"—the person who makes use of the knowledge elicitor's[1] products—needs to explore and represent the breadth, depth, and dynamics of his/her understanding of teams is an analysis method that:

- enables multi-level analysis and representation of his/her knowledge elements—from the data to its highest abstractions;
- enables re-combinable views of those knowledge elements; and
- enables static representations without extracting them from their context.

This paper describes the merging of two knowledge elicitation and analysis methods—Concept Mapping and Wagon Wheel Method—to advance the state of the science in understanding teams and teamwork. Concept Maps are meaningful diagrams that are used to represent and convey knowledge (Crandall, Klein, & Hoffman, in preparation). The Wagon Wheel Method makes explicit how teams communicate. The new merged method brings together the representational format and knowledge elicitation probes of the Wagon Wheel Method and the "propositional coherence" of Concept Mapping to address the needs of the knowledge elicitor and analyst studying teams. I also demonstrate features in CmapTools[2] (Cañas *et al*., 2004), a concept mapping utility that enables analysis of teams using large datasets while incorporating the analysis guidance of the Wagon Wheel Method. I suggest that this merged method enables a deeper understanding of team dynamics and provides the knowledge analyst with powerful representations to convey what he/she has learned.

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[1] For the purposes of this paper, I treat the "knowledge elicitor" and "knowledge analyst" as two separate actors in the study of team dynamics. The knowledge elicitor collects data on team dynamics, while the knowledge analyst seeks to analyze and represent the data. In actual practice, these roles are often not separate.
[2] http://cmap.ihmc.us/

2 Concept Mapping

As Hoffman notes in Crandall et al. (in preparation), Concept Maps "can be created by individuals who wish to lay out their own knowledge or… scaffold knowledge elicitation interviews with domain practitioners." In the context of this paper, the knowledge needing to be laid out is that of a knowledge analyst studying teams.

A primary differentiator between Concept Maps and other types of diagrams is the notion of propositional coherence. A concept map is a graphic display of concept names connected by directed arcs encoding propositions in the form of simplified sentences (Cañas, Ford, Brennan, Reichherzer, & Hayes., 1995). Concept Maps involve nodes and links. Concepts are represented in nodes, and their relationships to other concepts are specified by the links between them. Thus, node-link-node triples in Concept Maps form propositions; they can be read as stand-alone simple and meaningful expressions. When all of the triples in a Concept Map are well-formed propositions, the Concept Map is said to be "propositionally coherent" (Crandall et al., in preparation). Propositional coherence is an important aspect of the merged method.

3 Wagon Wheel Method

The Wagon Wheel Method can be used to elicit data for a number of purposes and in a wide variety of settings. It was developed by Klein Associates Inc. to enable an understanding of how teams communicate, and has been employed in a number of domains. The Wagon Wheel Method "provides a quick and easy snapshot of team communications. The goal of the method is to identify the main communication channels existing for each position on the team and the nature of those communications" (Klinger & Hahn, 2003, p. 21). It 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.

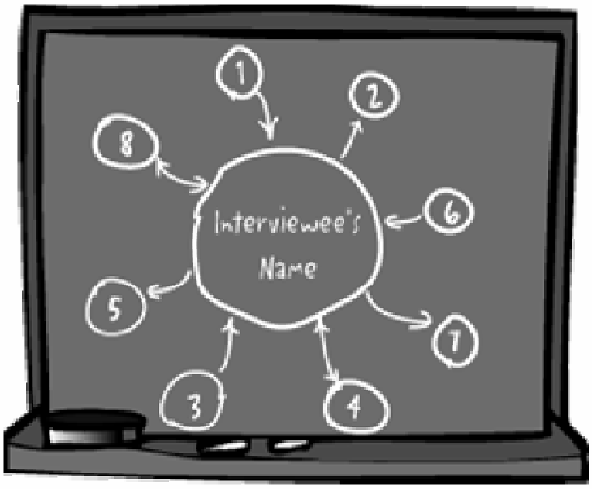

Figure 1. Wagon Wheel Method. The interviewee is the central node in a description of communication that is drawn during an interview.

Klinger and Hahn (2003) provide a detailed protocol for conducting the Wagon Wheel Method. As illustrated in Figure 1, the Wagon Wheel provides a look at a team from the perspective of individual team members. Each team member is interviewed about the other members with whom they interact. This knowledge elicitation procedure provides copious data as to the nature of the interactions by probing team members with questions such as:

- *What type of information is passed?*
- *From where did you receive the information you are transmitting?*
- *From where did he/she receive the information he/she is transmitting to you?*
- *Did you modify the information in any way? (The goal of this question is to determine if the information was simply passed in its original form or if it was altered, filtered, prioritized, etc., in any way.)*
- *What decisions does this information affect?*
- *How do you know they received the information?*
- *How do you know when to provide them with this information?*
- *Would you consider this piece of information to be critical to the team's success?*
- *What is the impact to the team if this communication line is broken?*

4 Merging Methods

The two methods, then, include key features for supporting the knowledge elicitor and analyst studying teams. The Wagon Wheel Method provides data collection protocols for eliciting knowledge and a representation format. Concept Maps require the knowledge elicitor to specify the relationships between nodes, or in the case of teams, team members.

4.1 Elicitation

The propositional coherence principle in Concept Maps provides a first step toward developing a new elicitation method. At their most basic structure, teams are groups of individuals who stand in some relationship to each other. Each team member's relationship with all of the other team members can, in some way, be specified, even if the specification is a null set (i.e., "has no relationship with").

Concept Maps can be useful in representing team organization and the nature of the relationships between team members by using the Wagon Wheel Method to guide elicitation. Knowledge elicitation can make use of Concept Maps to represent the data from the teams under study (see Hoffman in Crandall et al., in preparation, for guiding protocols for using Concept Maps in this way). Klinger and Hahn (2003, p. 21) suggest an analog approach for conducting the Wagon Wheel Method:

> The Wagon Wheel Method is best applied in a one-on-one interview setting. It is necessary to have a whiteboard or some other common point of reference for the elicitor and the interviewee to record the communication patterns.

Thus, one approach for knowledge elicitation that stems from merging methods is to make use of Concept Mapping during knowledge elicitation. The elicitor would "set up the parking lot" (Hoffman in Crandall et al., in preparation, p. 86) with the interviewee in the center and the teammates with whom he/she interacts around him/her in nodes. The knowledge elicitation session would proceed by capturing the answers to the Wagon Wheel probes in the links between nodes, as suggested in Figure 2. The directions of connections might also provide an opportunity to represent the directionality of information flow. And process interactions can also be represented. Concept Maps of each interaction could also be built post-elicitation, if the knowledge elicitor opts to use the analog whiteboard method. All of the maps can then be linked together to create a "knowledge model" of the entire team interaction.

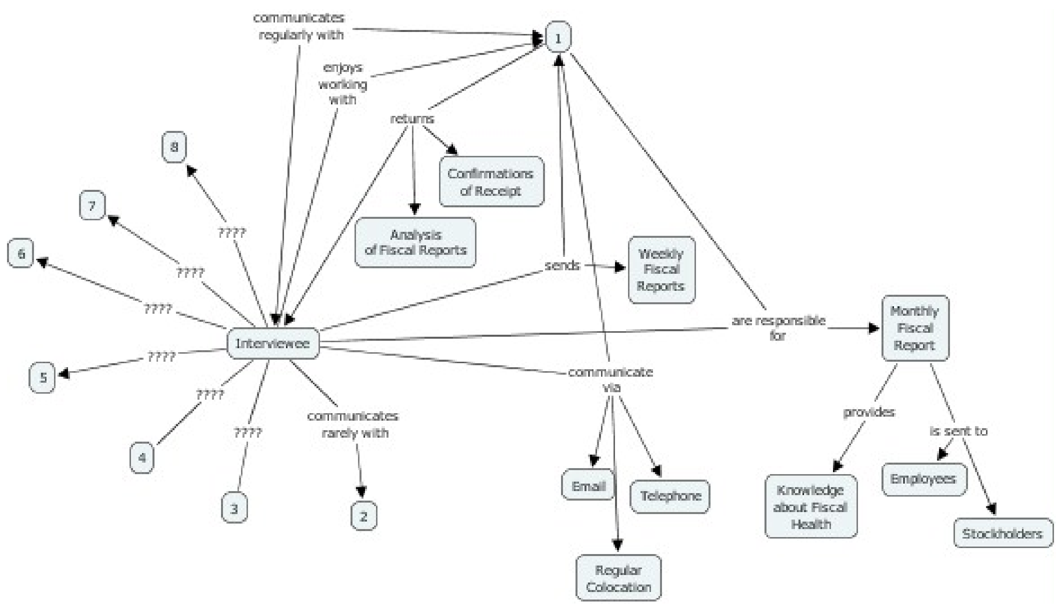

Figure 2. Using Concept Maps during elicitation.

4.2 Data Analysis

Whether capturing the knowledge elicitation with Concept Maps or using the analog whiteboard method, the real value added by merging the methods can be seen in data analysis. For data analysis, Klinger and Hahn (2003) recommended that analysts "develop the Wagon Wheel representations for each interview and then set them side-by-side. Viewing them together provides an overall view of the communications pattern. Although it can be helpful to combine the representations into one, [Klinger] found that for complex organizations this simply produced a spaghetti-like image that provided little or no data." The merged method provides a leap forward from this analysis process.

During analysis, the links emerge as the primary focus. The merged method takes the Wagon Wheel format and requires the knowledge analyst to specify the links between concepts, or team members. The Wagon Wheel calls for the elicitation of data elements in categories of information (e.g., *What type of information is passed? From where did you receive the information you are transmitting?).* An analytic judgment about these categories may serve as the link between nodes, and/or the analyst may create multiple links between concepts to represent different aspects of the interaction. Figure 3 demonstrates this level of abstraction. The data underlying the specification is not presented, but specifying multiple links provides a look at the nature of the interaction between the team members *from the point of the interviewee*. Using CmapTools the data supporting the specification of the links can be captured at the link by attaching resources (e.g., documentation of the Wagon Wheel interview, links to Concept Maps derived during knowledge elicitation).

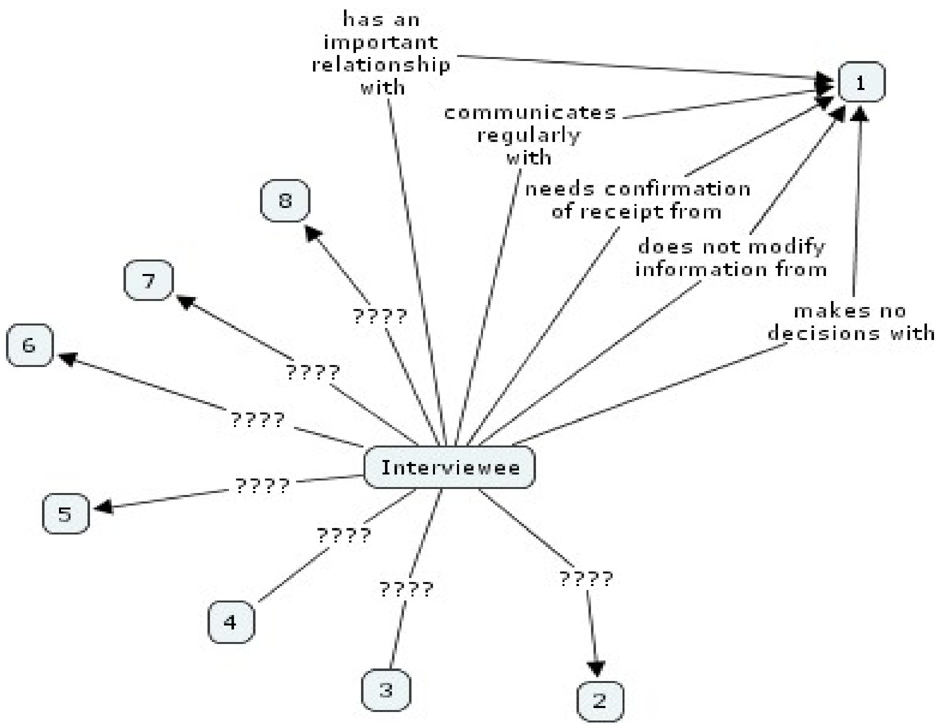

Figure 3. Using Concept Maps during analysis—first level of abstraction.

4.2.1 Nesting as an Analytic Technique

While exploring the data at this abstracted level is useful for gaining an understanding of interactions *between individual team members*, an even higher level of abstraction may be called for to truly get a feel for the workings of the team. CmapTools provides a number of features to support this type of analysis. Because multiple links may be specified between nodes, a still higher abstraction from the data can be specified. Nested nodes provide the option of building multiple links between nodes, then "combining" the links (read: children, in CmapTools parlance) and specifying the title of the cluster (read: parent, in CmapTools parlance). Figure 4 shows how this level of abstraction would be useful for exploring the team. Nesting can be used for a higher level of abstraction geared toward "typifying" interactions amongst team members. To perform this analysis technique, the cluster of links could be nested, thereby requiring the analyst to specify the relationship into a concise, propositionally coherent triplicate. That is, upon analysis of the data, the nested link reflects a more highly specified relationship. This analysis proves particularly useful for streamlining the data into an application-ready representation, as it requires the analyst to capture the "essence" of a relationship.

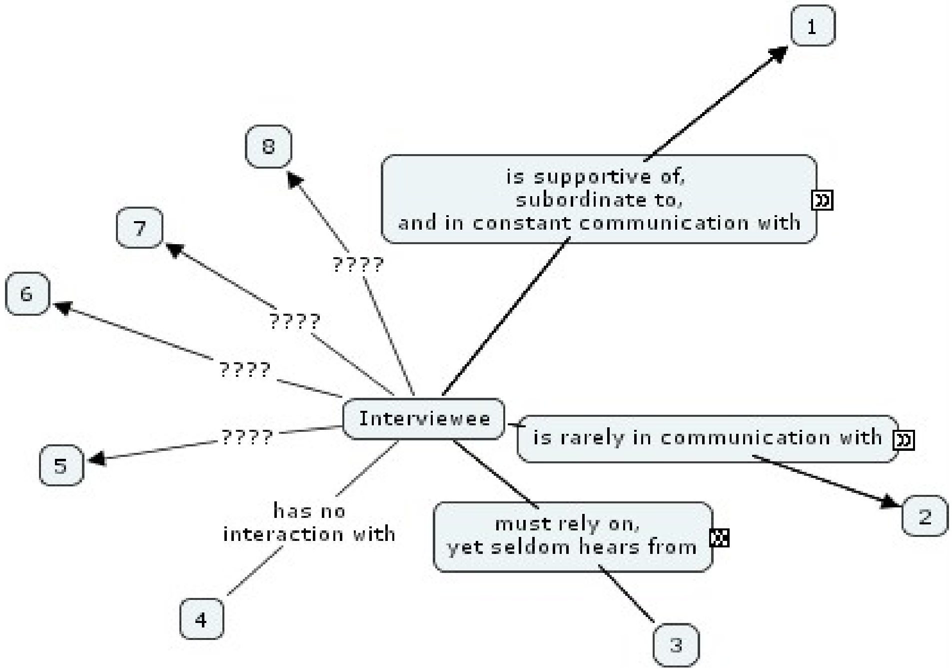

Figure 4. Using Concept Maps during analysis—second level of abstraction.

CmapTools also enable the importing of large datasets. Of particular interest for the merged method is the facility to import tab delimited text. Wagon Wheel interview data, or other data that indicates relationships between team members, may be captured into this format, then imported into CmapTools to create analysis-ready Concept Maps. Figures 5-7 present this approach via Concept Maps created with a dataset.

In February 2003, Klein Associates Inc. participated in an exercise at the Battle Command Battle Laboratory, Ft. Leavenworth, Kansas, USA. The experiment focused on the interactions among members of a brigade-level command cell (read: team), and was geared toward understanding how the members interact, and may interact in the future. Data gleaned from a collaboration support tool (GroupWise Systems) were collected during an experiment. Participants were required to enter data into the system regarding the nature of their interactions with other cell members—that is, qualitative statements characterizing their interactions with other cell members. The tool collected the data and produced it in spreadsheet format. The spreadsheets were reformatted into tab delimited text and imported into CmapTools to produce multiple Concept Maps, one for each participant. To create a "Super Concept Map" of the entire dataset, multiple Concept Maps were manually merged.

Much like the Wagon Wheel Method, the Concept Maps included the participant as one node, all of the team members with whom he/she interacted as other nodes, and his/her inputs to the collaboration tool as the links. Figure 5 demonstrates this from the perspective of the Plans Officer. It is immediately apparent from this view with whom the Plans Officer interacted in the cell. For cell/team members with whom he/she did not interact, no data were entered; thus no links were created.

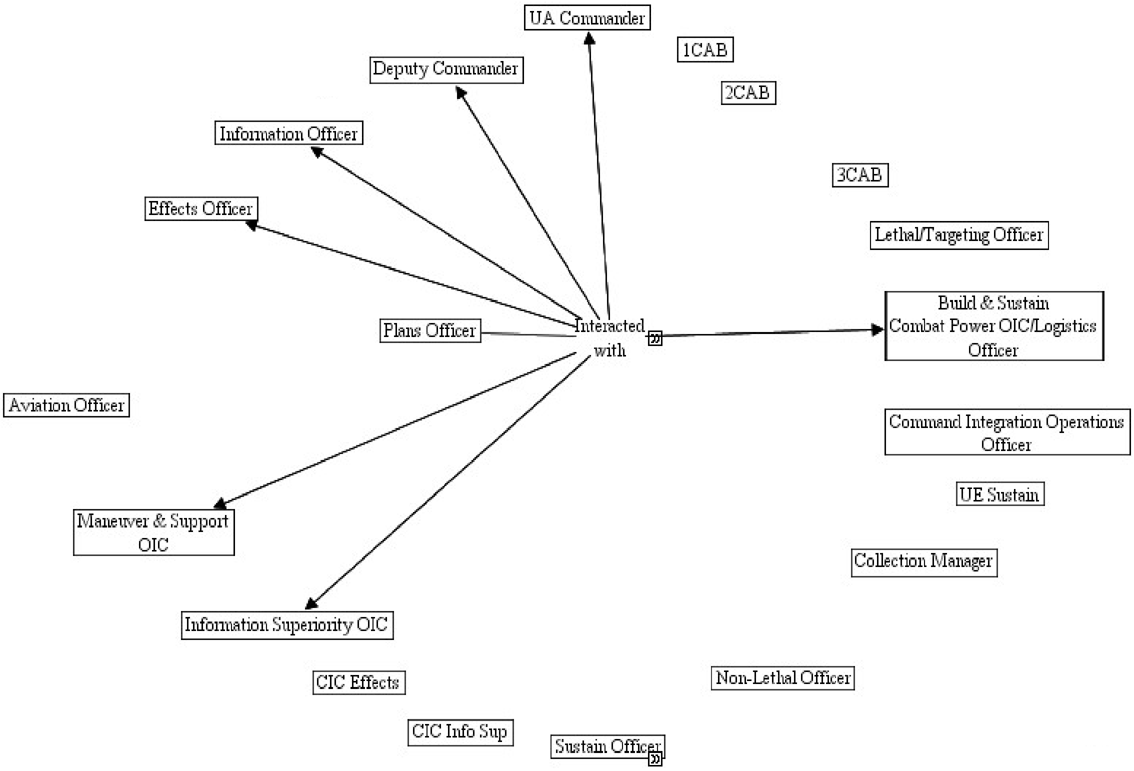

Figure 5. Using Concept Maps during analysis—imported dataset, plans officer view.

The contrasting view in Figure 6 from the UA Commander instantly demonstrates that he interacted with different team members.

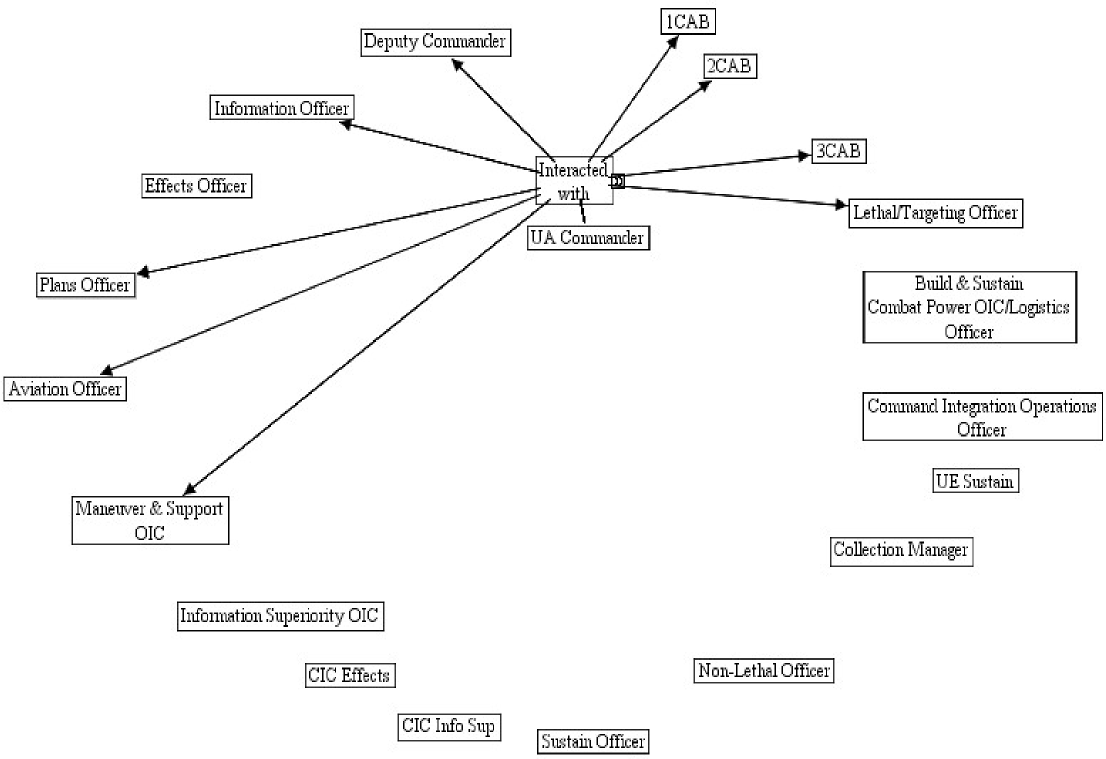

Figure 6. Using Concept Maps during analysis—imported dataset, UA Commander's view.

At this level of analysis, the data of each interaction is captured in the nested link, seen in Figure 7 for the UA Commander and his interactions with "1CAB." The nature of his interactions—as captured in his statements entered into the collaboration tool—are all captured under the nested link "Interacted with." Thus, they can be inspected during analysis on a case by case basis, or directly compared to other interactions of interest by placing them side by side.

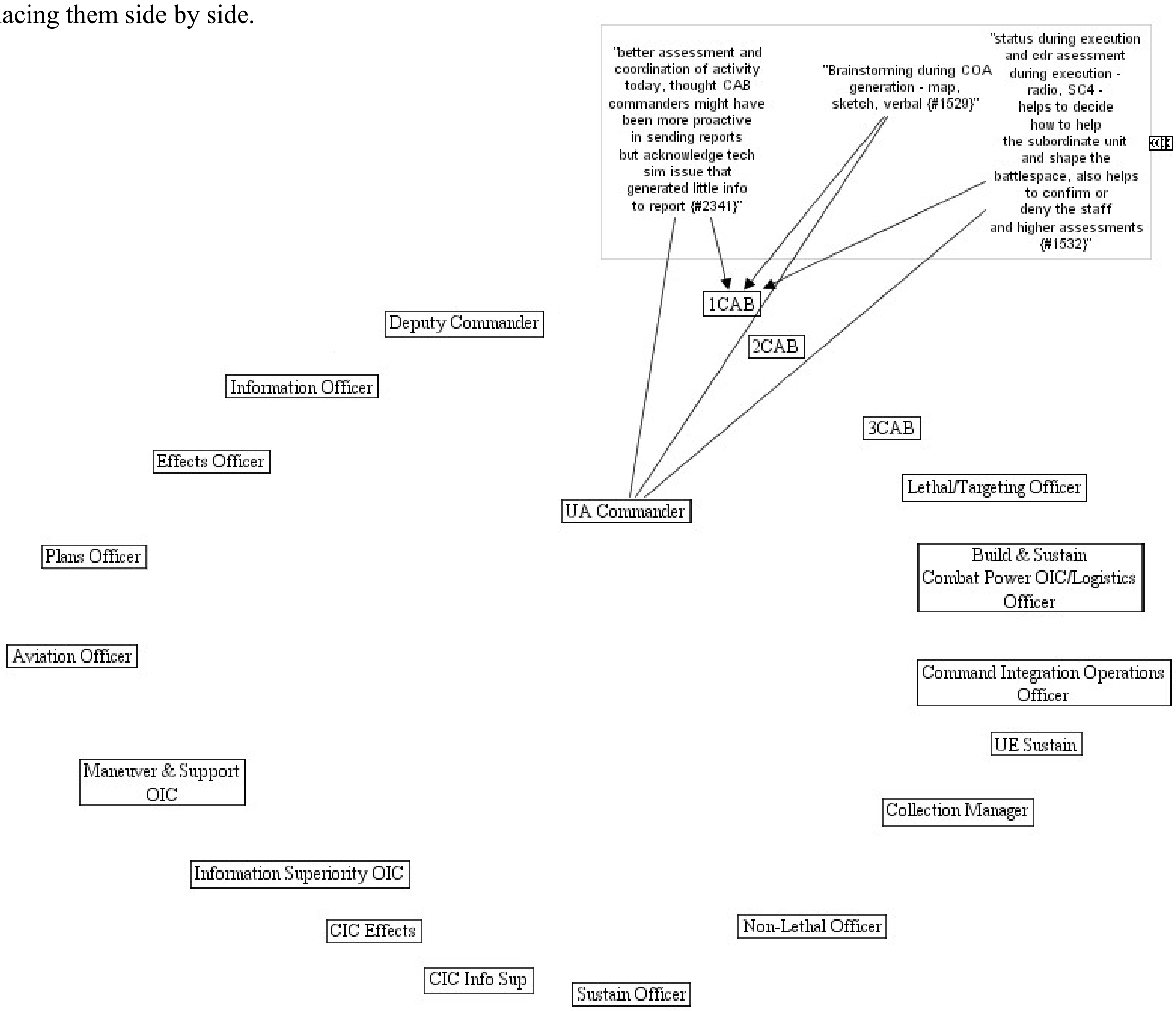

Figure 7. Using Concept Maps during analysis—imported dataset, UA Commander's interactions with 1CAB view.

5 Representation: Static Representations, and Dynamic Demonstrations Using CmapTools

As Figures 2-7 suggest, Concept Maps provide useful representations of team communications. Any interaction, or indeed interactions, between team members can be captured and displayed in a static representation. The advantages over other static representations include:

- Use of natural language (as opposed to a pre-specified modeling language)
- Appropriate specification of relationships (as opposed to wiring diagrams and organization charts that link but do not specify relationships between concepts)
- Representation of various levels of context (as opposed to the "all or nothing" analogue method of setting wagon wheels against each other).

CmapTools also provide the capability to create dynamic demonstrations. By merging multiple Concept Maps, and related resources, the knowledge analyst has the entirety of his/her dataset and analysis available. Relationships can be called into high relief, and demonstrated upon demand. Indeed, Figures 5-7 were created from the "Super Concept Map" noted above by hiding some relationships while highlighting others to produce static representations. The same "Super Concept Map" can be used to present analysis points of interest in a dynamic fashion. This self-contained, highly accessible knowledge model can prove invaluable when interacting with application developers who may want to see various levels of analysis, as well as the data elements.

6 Cautionary Notes

While the merged method clearly provides a leap forward for the Wagon Wheel Method, it must be noted that it presents at least two challenges to the emerging thought on the principles of Concept Mapping. First is the notion of morphology. While some suggest that Concept Maps should reflect a morphology "like hierarchies" (Hoffman in Crandall et al., in preparation, p. 80), others are less enthusiastic about this requirement (Cañas, personal communication, 2003). Clearly, the Wagon Wheel Method format is incompatible with this requirement.

Another challenge stems from the nested node analysis method enabled by CmapTools. Figure 7 shows the children within the nested node. Individually, these children violate the notion of propositional coherence. However, as a nested node in which the link is specified (either as an analytic statement or simply as a generic category, such as "interacted with"), propositional coherence is restored. The cautionary tale here is that the analysis product is not a Concept Map until all of the triples are well-formed propositions. This can also mark the end of the analysis!

7 Conclusion

The Wagon Wheel Method and Concept Mapping emerged out of separate fields of inquiry, for different purposes. This paper suggests that the study of teams and teamwork can be greatly enhanced by merging the best of both worlds at the stages of knowledge elicitation, analysis, and representation. The resulting merged method provides for new analytic techniques and representations that can be useful for developing and presenting both overarching and intimate knowledge of teams.

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Pamplona, Spain 2004

LOS MAPAS CONCEPTUALES EN HUMANIDADES: *EL QUIJOTE*, LA CULTURA

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Las humanidades, como objeto de análisis y enseñanza—prescindiendo, por tanto, de la creación literaria y artística que también son humanidades—se pueden distribuir en cinco disciplinas: lingüística, literatura, historia, filosofía y teología. En todas las disciplinas lo primero que se exige del profesor para ayudar a los estudiantes a aprender, es orden y clasificación. De manera particular, en filosofía y teología, la calidad de un pensamiento se mide por su carácter de sistema, y el grado de coherencia lógica del sistema. Orden, clasificación y sistema son sinónimos de lo que en este congreso estamos estudiando como mapa conceptual.
La bibliografía sobre mapas conceptuales atiende de manera casi exclusiva a conceptos de la física y la biología. Yo voy a tratar de construir el mapa ideal de dos objetos de las humanidades: El *Quijote*, la obra más universal de la literatura en lengua española, y el concepto de *cultura*, tan rico en aspectos que es muy difícil de reducir, no sólo a un mapa, sino a una definición consensuada como tal concepto. Sin embargo, la idea de cultura nos interesa a todos, porque es hoy es un territorio disputado, no sólo en sentido político, sino en un setnido filosófico, que merece la más seria reflexión académica. Por una parte la globalización nos lleva progresivamente a la interdepencia y a la homogeneidad, y por otra se acentúan las diferencias llamadas culturales hasta el extremo de los estallidos terroristas, y se defiende o ataca el "multiculturalismo", otro concepto difícil de entender, porque depende de la idea de cultura.

1 Concepto del concepto

El profesor Novak define los conceptos como "regularidades percibidas en hechos y objetos" (González, Morón, Novak, 2001, 213). Creo que la definición es aceptable; el problema en las humanidades es la complejidad de los conceptos: "humanismo," "identidad colectiva," "la obra de Borges," etc. Sin duda estos conceptos tienen sentido en la medida en que poseen algún núcleo regular de significado, pero el problema radica en establecer ese núcleo y en ver cómo se relaciona con sus múltiples ramificaciones.

Los conceptos científicos y los humanísticos se distinguen en el origen de la regularidad. En el concepto de átomo y de agua se trata de realidades naturales inmutables. En estos casos es posible llegar a conceptos unívocos, y si no se llega será por límites de nuestro conocimiento o por error. Pero junto a los conceptos que responden a realidades naturales están los sociales y culturales, formados por los mismos factores que forman las sociedades: la combinación de imposición de fuerzas objetivas y aceptación libre, y la evolución histórica. "Humanismo," por ejemplo, es el movimiento cultural iniciado en Italia en el siglo XIV, que se difunde por toda Europa y los primeros centros culturales de América hasta el nacimiento de la modernidad con la nueva física de Galileo y la nueva metodología científica de Bacon y Descartes. La definición, de nuevo, es válida, pero a nadie se nos oculta la dosis de convención implicada en el acuerdo de que Petrarca es el fundador del movimiento, la complejidad de explicar un concepto que resume la cultura occidental de 300 años, y la convención de establecer cortes en el continuo que es la historia. Ahora bien, esa complejidad hace los mapas más necesarios e iimprescindibles que en las ciencias. Nuestros mapas no describen territorios bien acotados, sino la "Galaxia Gutenberg".

Todos los conceptos tienen un núcleo que los constituye en lo que son (su regularidad); pero los conceptos que son muy complejos, como "arte," "literatura" o "novela," antes que presentarnos su cara constitutiva, nos presentan la negativa. No sabremos decir exactamente qué es una novela, pero por de pronto sabemos que no es un poema o una obra de teatro. Podemos, pues, establecer la tesis de que los conceptos humanísticos son en su primera faz diferenciales, más que directamente definidores. En algunos casos, lo diferencial va expresado en la misma palabra que denota el concepto: neo-kantismo, pos-modernidad.

Un esquema de los conceptos, para situar los humanísticos en su esfera correcta sería el siguiente:

Todos los conceptos—los de ciencias y los de humanidades—son regularidades observadas en hechos y objetos. Pero la regularidad en los conceptos humanísticos no es un hecho natural sino histórico. Los conceptos históricos son:

Colectivos (el español, musulmán, burgués, proletario)
Culturales (arte, filosofía, posmodernidad).

2 EL QUIJOTE

Por razones de tiempo me limito a la primera parte, publicada en 1605. ¿Qué se hace para explicar una obra literaria? Por de pronto, leerla con atención: *análisis*.

Del análisis debemos inducir las coordenadas sobre la estructura, los personajes y los términos o pasos concretos que, a nuestro entender, son los más significativos del texto: *síntesis*.

Y en definitiva, ante una obra de 1605, siempre hay que preguntarse por qué merece la pena pasar el tiempo con un texto antiguo, cuando la realidad actual nos ofrece tantos flancos dignos de estudio: *valoración*.

Análisis, síntesis y valoración constituyen el esquema de un acercamiento aceptable, puesto que intenta abarcar todos los aspectos de la obra literaria.

EL ESTUDIO DE LA OBRA LITERARIA
SE REALIZA EN TRES MOMENTOS:

Análisis Síntesis Valoración

Considero necesario observar que el esquema, dividido en tres momentos, en la práctica no se puede ni debe aplicar en un sentido linal. En el análisis decimos, por ejemplo, que hay ciertos pasajes geniales, lo cual es ya una valoración, y la valoración en realidad es la culminación de la síntesis, que tampoco se reduce a la mera enumeración de aspectos descubiertos en el análisis. Un texto literario, más que un territorio en cuya exploración se avanza en línea recta, es una esfera en la cual se toma un punto de partida y se sigue un orden lógico, que siempre es lineal, pero sin perder de vista el punto de partida, y siempre para volver a ese punto.

Heidegger puso de moda el concepto de "diferencia", como el punto de encuentro y distanciamiento de dos conceptos, que sólo se pueden entender en esa mutua interdependencia. En un aspecto, la diferencia corrige la idea de dialéctica de Hegel, plasmada en los estadios de tesis, antítesis y síntesis. Todo saber—en esto concuerdan el científico y el humanístico—comienza con una noción y un proyecto de estudio—tesis—avanza con atención a detalles independientes de la primera noción—antítesis—y termina recobrando la noción primera con un conocimiento más exacto de ella. Ahora bien, la dialéctica, así entendida, presupone acierto, y por tanto un avance. Pero si la investigación no está bien dirigida y acabamos en conceptos erróneos, hemos hecho un esfuerzo, pero sin resultados. Se ha dado, por tanto, una diferencia, pero no dialéctica en el sentido de progreso. En ciencias parece más fácil detectar el error; en cambio, en el estudio del *Quijote*, por ejemplo, es muy difícil acusar un estudio de totalmente erróneo. Vivimos más en el camino que en la posada; en la diferencia, más que en la dialéctica.

Siguiendo el criterio de lo más sencillo a lo más complejo, creo que el mapa inicial sobre la primera parte del *Quijote* debe ser el siguiente:

EL INGENIOSO HIDALGO DON QUIJOTE DE LA MANCHA

es una

NOVELA ESCRITA POR MIGUEL DE CERVANTES SAAVEDRA

impresa por

JUAN DE LA CUESTA, EN MADRID, 1605

No sé si a este esquema lo podemos llamar propiamente mapa, pero sí ofrece un criterio de organización para la enseñanza. En definitiva, una buena exposición del *Quijote* podía organizarse en torno a los siguientes apartados:

El Quijote
Novela de
Miguel de Cervantes Saavedra
Impresa en Madrid en 1605.

No voy a comentar esta última línea, aunque es muy importante, porque el lugar y fecha de un libro nos refiere a su primera recepción por parte de los lectores, a la circunstancia histórico-social del autor, y a detalles como las características de impresión del libro.

El Quijote y el "ingenioso hidalgo"

Aquí entra el esquema de análisis, síntesis, valoración. Pero el título que nosotros le damos en nuestra conversación, no es el original. El título de Cervantes es: *El ingenioso hidalgo Don Quijote de la Mancha.* En el primer capítulo nos enteramos de que el hidalgo se convierte a sí mismo en caballero andante. Ahora bien, las historias caballerescas se titulan en general del modo siguiente: *Historia del esforzado caballero ...*
Cervantes no anuncia un libro de caballería, sino una historia sobre un "ingenioso hidalgo". Ingenio es la función creadora del entendimiento. La otra es el juicio, que ordena y selecciona las ocurrencias del ingenio. La locura de don Quijote consistirá en que pierde el juicio, y se le queda suelto el ingenio, proclive a todas las ilusiones. En todo caso, el "ingenio" no es la mejor base natural para producir un caballero. Los caballeros eran jóvenes apuestos y hermosos; don Quijote es un hijo seco (sin variedad, monótono), avellanado (hidalgo viejo), lleno de pensamientos varios". "Vario" es un adjetivo que acompaña con mucha frecuencia al sustantivo pensamiento en las literaturas europeas clásicas (también en Shakespeare). Significa los pensamientos que nos vienen a la mente sin nuestro control, es decir, son las ocurrencias carentes de "mapa conceptual".

En el mapa propuesto el significado de "ingenioso" lo hemos descubierto por contraste con los libros de caballería. Tenemos el primer caso de lo que he llamado aspecto diferencial del concepto.

Desde las primeras líneas del *Quijote*, se enfrenta el lector con un hidalgo que ha perdido el juicio y se hace caballero andante en un mundo en que ya no existe esa institución. El libro no narra la vida del hidalgo desde su niñez, sino que comienza cuando tiene cerca de cincuenta años. También aquí el sentido (análisis) y el valor artístico de la obra surge de una diferencia: El caballero tiene que ser joven, y un viejo de cincuenta años está en edad de retirarse de la caballería, no de comenzarla.

Cuando descubrimos que el *Quijote* es una parodia de los libros de caballería, percibimos otro concepto diferencial, ya que la parodia es un texto dependiente, que sólo se entiende desde el texto parodiado. Sin embargo, el *Quijote* es parodia sólo en un sentido secundario. Lo importante es su significado como creación original. Por eso es posible entenderlo y apreciarlo aunque no se conozcan los textos parodiados.

Al mismo tiempo, en la parodia se descubre un nuevo concepto: el humor, aspecto básico de la calidad artística y humana del libro, y concepto complejo dentro del complejísimo concepto *Quijote*. También del humor podía intentarse un mapa conceptual.

Como análisis, yo creo que la primera parte se puede distribuir en los siguientes segmentos:

Prólogo a capítulo VI (Primera salida)
Caps. 7 a 22: Entrada de Sancho, sucesión episódica de escenas
Caps. 23 a 36: Esbozo de un argumento: la ventura resuelta por don Quijote
Caps. 33-52: Novelas, el poder de la lengua, crítica de los libros de caballería.

La aparente inconsecuencia de que la sección tercera vaya hasta el capítulo 36 y la cuarta comience en el 33 se debe a que los capítulos 33-35 interrumpen la aventura de Cardenio y la princesa Micomicona con la lectura de una novela intercalada, y esa novela se relaciona mejor con la discusión sobre la novela que viene en la última sección.

La estructura propuesta para la primera parte es mía. Esto quiere decir que no es canónica ni está generalmente aceptada. Por supuesto, no es éste el lugar de justificarla, pero en todo caso, aunque no estemos de acuerdo en una cierta distribución estructural, lo estaremos al menos en las divisiones innegables: el Quijote se divide en dos partes, el caballero realiza tres salidas, etc.

Como ejemplo de síntesis daría el esquema que define a Sancho: Sancho criado, Sancho, Sancho sentido, Sancho lengua.

1. Criado: Cuerpo grueso, mal conformado para actividades de caballero, no ejercitado en trabajo liberal, sino en trabajo físico de campesino; su único horizonte es el interés por aán de sobrevivir; no tiene aspiraciones espirituales, sueña con el gobierno de la ínsula, pero cuando cae derrotado, alcanza su máxima sabiduría: “Yo [criado de cuerpo y de alma] no nací para ser gobernador” (II.53).

2. Sentido: Sancho ve los molinos, pero don Quijote le dice que “no sabe.” Efectivamente, Sancho no sabe leer ni escribir; es “agudo,” o sea, posee una inteligencia típica del siervo, no de sñor; y cuando dice alguna frase que se eleva sobre su horizonte mental, es porque la ha oído a su señor, al cura de su pueblo o al predicador de la cuaresma.

3. Lengua: Una mente de ese nivel no tiene lengua propia, sino el lenguaje estereotipado de los refranes.

Sancho como personaje, más que un mapa es acreedor a un perfil, y creo que los tres rasgos señalados dibujan ese peril con bastante facilidad. De nuevo, desde el punto de vista didáctico creo que se ofrece un esquema lógico y que ayuda al aprendizaje significativo.

Novela

El *Quijote* es una “novela”. Este nombre no aparece en 1605, ya que entonces ese nombre sólo se aplicaba a la novela corta, como lo hace Cervantes en sus “novelas ejemplares”. Para nosotros hoy novela es una categoría cómoda, y sin duda contiene notas que producen un concepto como “regularidad” (Novak); pero, antes que catalogar esas notas positivas, el concepto de novela es negativo o diferencial. Quizá no sepamos con claridad lo que es una novela, pero al usar el término, decimos que no es un poema o una obra de teatro.

En torno al término novela, que designa el género literario del *Quijote,* el esquema sería:

1. ¿A qué género perteneció el texto para Cervantes y sus contemporáneos?
2. ¿Cuándo se aplicó el título de novela a obras extensas como el *Quijote*?
3. ¿Cómo se relaciona el Quijote con la novela moderna?
4. ¿Es el *Quijote* una “gran novela” y cuáles son los criterios de la “grandeza”?

El autor

“Miguel de Cervantes Saavedra”. El nombre del autor al lado del título y género de la obra no denota en sentido primario una distinción con respecto a ella, sino la inseparable fusión del autor y su texto, ya que los autores están siempre, aunque en distinto grado, presentes en su obra, y Cervantes está muy presente en el Quijote, dándonos sus propias reflexiones según va creando su novela. En definitiva, los únicos datos de la vida de un autor que interesan a la hora de interpretar su texto, son los que han dejado huellas en el texto. Importan poco las transacciones económicas o las aventuras amorosas que pudiera tener Cervantes, si no sirven para explicarnos ideas, imágenes y datos de su novela.

En el aspecto de la relación autor-obra, sólo puedo referirme al prólogo. Considero (visión personal, pero mi intención es captar el contenido objetivo del texto) fundamentales estas palabras de Cervantes: “Yo que, aunque parezco padre soy padrastro de don Quijote” (Prólogo). Creo que estas palabras justifican la ordenación en torno a los términos padre y padrastro.

Cervantes-padre:
Quisiera que este libro, como *hijo del entendimiento...*
En la naturaleza cada cosa *engendra* su semejante
El mal cultivado ingenio mío engendra la historia de un *hijo* seco...
Bien como quien se *engendró* en una cárcel
Acontece tener a un padre un *hijo* feo, y el amor que le tiene...

Cervantes-padrastro:
Pero no he podido yo contravenir el orden de naturaleza
Yo que aunque parezco padre soy padrastro de don Quijote
Entró a deshonra un amigo.

En las afirmaciones de paternidad, Cervantes da el texto como salido de sus entrañas, que en un escritor pueden ser dos: la *fantasía loca* (ingenio) como la que utilizan los autores de los libros de caballería, y *el entendimiento* (ingenio con juicio), que utiliza la ficción en sentido realista y como análisis de experiencias humanas universales.

Pero el autor no domina totalmente su creación. Aquí introduce Cervantes una experiencia genial sobre la escritura: *escribir es una lucha entre el querer y el poder*. Todos deseamos hacer el mejor artículo del mundo, pero damos lo que podemos. Escribir es un punto de encuentro entre el esfuerzo y la inspiración. En la medida en que nuestro escrito es algo "inspirado", es un hijo que recibimos al casarnos, y sólo somos su padrastro. De hecho, Cervantes, según propio testimonio (I.9), se limitó a pagar a un joven morisco de Toledo la traducción de la historia de don Quijote, escrita en árabe por Cide Hamete Benengeli.

También es padrastro del prólogo. Cervantes dice que estaba concentrado, esforzándose por escribirlo, y no le salía nada; entró un amigo al que no esperaba, y cuando surgió el diálogo, se escribió el prólogo. El análisis de la escritura que Cervantes nos da y que vale para todo el *Quijote,* permite el siguiente mapa:

ESCRIBIR ES: DESDE EL PUNTO DE VISTA DEL:

Autor: Lucha entre el querer (intención) y el poder (inspiración)
Proceso de aprendizaje antes que intento de enseñar
Esfuerzo por conformar un texto cerrado, y conjunto de saltos que a veces pueden producir inconsecuencias y hasta contradicciones en el texto
Diálogo del autor consigo mismo, con su tema y con sus lectores

DESDE EL PUNTO DE VISTA DEL:

Texto: El texto es el resultado de la lucha entre la intención y la capacidad del autor
El texto es a la vez abierto y cerrado
El texto lleva las marcas del esfuerzo de conformación y de los saltos

DESDE EL PUNTO DE VISTA DEL:

Lector: El texto es una llamada a la lectura más objetiva posible
El texto tiene dos aspectos: la realidad tratada y los aspectos formales, que en la obra literaria son a su vez aspectos del contenido.

Como se ve, estos esquemas son fundamentales a la hora de describir conceptos, tratan de ser objetivos, pero son al mismo tiempo creación personal, y por tanto, no gozan del consenso que hay en las ciencias para ciertos conocimientos que ya parecen inamovibles.

3 LA CULTURA

¿Qué parámetros nos pueden dar una definición de cultura que sea lo más completa posible y en el orden más lógico posible? Lo primero que podemos distinguir es la cultura del individuo y la cultura como fenómeno social. Pero esta distinción, tan clara, no responde a la articulación de la realidad, ya que el individuo es inherentemente social, y por tanto, los caracteres de la cultura del individuo tendrán ya esa dimensión social.

Lo primero que asociamos con la cultura en el individuo es el saber: El individuo culto sabe muchas cosas y las sabe bien, de manera ordenada. Pero el concepto de cultura no se reduce al saber, sino que implica unas connotaciones de conducta. Se suele decir de algunos médicos que son muy competentes, pero son muy brutos (incultos), porque ante la experiencia repetida del dolor han perdido la sensibilidad si alguna vez la tuvieron. Y no es sorprendente encontrar algunas personas con doctorado que nos parecen tontas. En cambio, consideramos culta a la persona que muestra generosidad y solidaridad frente a las necesidades o dolores de los otros. La relación de una persona con otra se caracteriza por:

a) la atención, o la anticipación de las necesidades el otro;
b) la consideración o decisión de interpretar las acciones del otro atribuyéndole la mejor de las intenciones, y

c) la comprensión, o abstenerse de condenar los actos inaceptables de los otros, mientras no se tenga conocimiento de su malicia intencionada.

1. Atención, consideración y comprensión hacia los demás hacen a una persona culta, aunque no tenga una formación acreditada con títulos oficiales.

2. La cultura, ya en el plano social, es un contenido canónico de saberes. En la historia intelectual moderna, inspirada en Kant y popularizada en España a principios del siglo XX por el joven Ortega y Gasset, la cultura es ciencia, ética y estética, o sea, el esfuerzo sistemático y riguroso de conocer la realidad. Pero ¿quién conoce la realidad?

3. En el juego del individuo y la colectividad, ese conocimiento no se da en ingún individuo, sino que es el mundo del conocimiento: lo que llamó Karl Popper "el tercer mundo". Popper dice que existe el mundo real con sus contornos indefinidos, objeto perpetuo de nuestra invetigación (primer mundo). Existe el conocimiento individual, siempre muy limitado (segundo), y existe el mundo del conocimiento, que es el objetivado en los depósitos que son las enormes bibliotecas. La cultura es todo ese saber acumulado, lo que hoy llamamos el mundo de la información, accesible en muchos casos en nuestros ordenadores.

4. Cultura es también el conjunto de hábitos tradicionales de conducta que rigen en una sociedad: expresión lingüística, artística, organización social, usos convertidos en valores (derechos y costumbres, alimentación, relaciones familiares y de género, ritos religiosos y de la convivencia civil, espectación sobre la conducta y modales de las personas integrantes de esa sociedad). Esta dimensión es la que estudian los antropólogos, y se suele llamar "cultura popular." Mi esquema para la definición de cultura sería el siguiente:

CULTURA

	Sensibilidad Saber
Plano de la cultura personal	
	Conocimiento sistemático de la realidad: ciencia, ética, estética (Kant)
	Ciencia, ética y estética en cuanto "tercer mundo", no poseído por ningún individuo, incluso por los mismos creadores de esos productos culturales
Plano de la cultura objetivada	Los derechos humanos: cultura sin adjetivos
	Cultura "popular": distinta en distintas sociedades.

La llamada cultura popular es:

A) El plano de los sentimientos, usos y costumbres en que todos nos encontramos como hombres, al margen de jerarquías. En esto sigue siendo universal. Por eso,
B) Se refiere a los ritos que nos tocan en lo esencial de la vida: nacimiento, desarrollo, matrimonio, muerte. Los distintos ritos son ya particulares.
C) En lo particular, la cultura puede adoptar hábitos bárbaros o salvajes: mutilación, discriminación, violación de los derechos humanos.
D) La cultura popular deriva y a la vez alimenta la cultura objetiva. La concepción del mundo (ciencia), los libros sagrados (ética) y a suv ez el reflejo en imágenes de las creencias colectivas (estética) condicionan la cultura popular.

Toda cultura particular se define por tres factores: lengua, historia y referencias mutuas entre los miembros que comparten esa cultura. La lengua permite y sugiere ciertas asociaciones que producen sistemas de ideas diferentes en unas lenguas de otras (refranes, canciones, poemas, matices de expresión—de ahí la dificultad de la traducción como vehículo de inteligencia—morada de sus hablantes). Pero la misma lengua-*langue* (Saussure) puede ser vehículo de distintas culturas, según la historia de una determinada sociedad. Los países latinoamericanos hablan todos español como *langue* y en gran medida también como *parole*, pero tienen orígenes distintos de los españoles, mutuas referencias sin relación con España, y relaciones con otros países y culturas que tampoco son las de España. De ahí que con la misma lengua podamos tener culturas diferentes.

Por otra parte, una cultura no está sólo definida por la nacionalidad. Un católico en un país musulmán puede hablar árabe, sentirse muy patriota en su nación, y sin embargo, en el aspecto religioso está más cerca de Roma que de la religión predominante en su país. Sus relaciones con Roma penetran su cultura y le crean una particular situación con respecto a su patriotismo. Baste recordar la posición de los católicos en China. En este sentido, cuando un Estado tiene una cultura oficial, puede llegar a imponer el criterio étnico sobre otros criterios legítimos de socialización, y degenera en tiranía. En este caso, la pretendida identidad cultural es una forma de salvajismo.

El esquema anterior permite analizar el alcance y límites del multiculturalismo. En el plano individual no creo que se puedan distinguir diferencias culturales en el aspecto de sensibilidad, o sea, la atención a las necesidades del prójimo, como ser humano, al margen de cualquier determinación étnica, religiosa o cultural (Parábola del Buen Samaritano del Evangelio).

También en el aspecto individual cabe un grado mayor o menor de cultura intelectual: somos más cultos cuanto más reconozcamos nuestras limitaciones y mejor actitud tengamos de escuchar en vez de hablar. Más allá del individuo, la cultura científica objetiva puede caer en un pragmatismo insensible e inmoral, como hemos visto en la aplicación de la ciencia al crimen, sobre todo en el siglo XX y en lo que va del XXI.

Y en el terreno de la cultura popular, no puede caber comprensión para un pluralismo cultural que viole los derechos humanos. Las costumbres bárbaras y salvajes, por muy aclimatadas que estén en una sociedad, no se pueden considerar cultura.

Los adjetivos de la cultura

El salvajismo y la barbarie no provienen nunca de la cultura, sino de sus adjetivos. Como individuos humanos estamos insertos en un medio social que nos constituye como individuos; por consiguiente, sin ese medio social no existiría la persona, y a la vez ese medio o ambiente puede afectar a nuestra individualidad hasta destruirla. Basta pensar hasta qué punto la malla de la mentira de algunos políticos puede obturar nuestra capacidad de pensar. El medio social concreto en el que existimos le pone calificativos a la cultura, hace posible el multiculturalismo, y origina la posibilidad de la barbarie.

Tomando el YO, como concepto de nuestra persona, las categorías más importantes de ese ambiente social que nos constituye como tales personas, se pueden clasificar con cierta exactitud en el mapa siguiente:

YO-edad
género
raza
pueblo
nación
estado
religión
clase social
profesión
asociaciones libremente aceptadas.

De nuevo, la clasificación es una intuición personal mía. Pero intenta superar todo subjetivismo y describir fielmente la realidad. La prueba de su valor objetivo consiste en que el lector vea si tiene sentido, y si encuentra mejores categorías, corrija mi esquema y de esa manera me enseñe. Como nos enseñaba Cervantes, aprender es dialogar.

La clasificación sigue el criterio de lo más universal a lo particular: Lo común a todos los humanos es que todos, hombres y mujeres, nos hacemos viejos. Luego viene la primera diferencia: la humanidad se divide en dos géneros: hombres y mujeres. En tercer lugar viene la diferencia de razas, y a continuación las diferencias étnicas, donde incluyo los conceptos de pueblo, nación y estado: el navarro, el español, el europeo. Pero la identidad colectiva no es sólo étnica; las religiones nos unen o dividen al margen de las fronteras de nuestro Estado. En los últimos lugares he puesto las categorías de clase social, profesión y asociaciones libremente aceptadas.

En algunos casos quizá sea imposible definir conceptualmente los rasgos de una u otra determinación social, pero todos conocemos el serio impacto de esas categorías cuando vemos que en nombre de identidades étnicas y religiosas se cometen actos de terrorismo, y en un orden más inocente, pero por eso más extendido, se cometen actos de discriminación. Discrimindción es toda preferencia o postergación no fundada en nuestra actuación o capacidad percibida, sino en cualquiera de las categorías en las que estamos insertos: edad, género, raza, etc. El tema de la identidad colectiva se presenta como objeto de las humanidades en la obsesión que existe en descubrir y mantener la identidad, sobre todo en las sociedades poscoloniales o en aquellas que se sienten perseguidas.

4 Conclusión

Los dos ejemplos dados muestran la virtualidad y límites de los mapas ante conceptos muy complejos y teñidos de anécdota histórica, como son los humanísticos. En realidad yo no he construido mapas, pero he aportado criterios de ordenación del saber fundados en la subordinación de los conceptos particulares a los universales, y en la mutua interacción de unos conceptos con otros en la esfera que constituye el conocimiento humanístico.

Los esquemas lógicamente ordenados son el mejor instrumento para aprender. Normalmente entendemos el verbo aprender como contrapuesto a enseñar, y en esta contraposición se deslizan subrepticiamente las connotaciones de parividad frente a actividad. En este caso los mapas serían instrumentos para que el alumno asimile ciertos contenidos que el maestro desea enseñarle. Pero nosotros debemos investigar la función de los mapas como actividad intelectual, o sea, como articulación de la realidad, que el investigador más activo descubre. En definitiva hay mapas para el alumno porque antes la realidad le ha impuesto su articulación al profesor. De ahí que los mapas no sean sólo instrumentos para llegar a saber, sino el saber o conocer mismo. Sólo hay conocimiento, decía Hermann Cohen (1902), donde hay sistema. Por eso el conocimiento es construcción, no subjetiva, sino respuesta a la estructura de la realidad.

¿Nos sirven los mapas en este esfuerzo del aprender creador? ¿Tienen el físico y el biólogo algún mapa a su disposición cuando planean un proyecto en su laboratorio? El aprender creador tiene dos momentos: el de invención, y el de selección y ordenación (invención-ingenio y disposición-juicio, decían los retóricos antiguos). Creo que el segundo momento, el de selección y sistematización, es siempre, de una forma u otra, la producción de un mapa. Las ideas que expongo en este trabajo se me han ocurrido durante años, y a la hora de escribirlo me han venido en un determinado orden. Pero en esta versión, corregida y reelaborada, he reorganizado todas las anteriores. ¿Por qué reorganizamos un escrito nuestro? ¿Hemos cambiado de pensamiento desde el día en que escribimos esa versión que arrojamos a la papelera? Reorganizar un escrito nuestro es dejarnos guiar por la estructura objetiva de la realidad, frente a las ocurrencias subjetivas que se nos han impuesto en fases anteriores del escrito. Y la expresión de esa estructura objetiva es el mapa. Naturalmente, mi última versión puede ser más deshilachada que la primera, pero eso ya no será resultado de mi intención, sino de mi limitada capacidad.

Ausubel y sus seguidores partieron de la distinción entre aprender memorístico —*rote learning*— y aprender significativo. Creo que hay otra dicotomía importante para el investigador en humanidades: aprender *espontáneo* y aprender *ordenado*. De nuevo, en la línea descrita por Cervantes, escribir es un conjunto de saltos espontáneos y un esfuerzo de ordenación. Y este esfuerzo de ordenación no tiene más fin que reflejar con la mayor fidelidad posible la articulación de la realidad.

Los conceptos humanísticos son ya muy complejos cuando designan un objeto como el concepto *Quijote;* pero además, no designan realidades naturales, sino históricas, que han surgido en situaciones concretas y se desarrollan en trayectorias de latencia y vigencia. No se explican, pues, con la razón pura, sino con la razón histórica. Por eso no es siempre posible establecer entre ellos una relación de efecto que reciba explicación de una causa (la *Erklärung* de Dilthey), sino relaciones de mutua dependencia y diferencia, de forma que entenderlos (el *Verstehen* de Dilthey) requiere construir, no un mapa estático, sino un mapa de fuerzas.

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Concept Maps: Theory, Methodology, Technology
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A SCIENCE EDUCATION RESEARCH PROGRAM THAT LED TO THE DEVELOPMENT OF THE CONCEPT MAPPING TOOL AND A NEW MODEL FOR EDUCATION[1]

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1 Introduction

When I began my graduate studies in 1952 at the University of Minnesota, the only psychology of learning presented was *behavioral psychology*, based largely on research with rats, cats and other animals. The only philosophy of knowledge, or epistemology, I was taught was *logical positivism*, for which the Philosophy Department at Minnesota was world famous. I did not see much value in behavioral psychology as a theory to guide research on human problem solving and ways to enhance this ability, which was the subject of my PhD thesis. Nor did I see value in a view of knowledge creation that centered on proving axioms and logically deriving new knowledge from basic premises, a view that did not appear to apply to the work I was doing in laboratory research in the Botany Department.

Although there was the work of Bartlett (1932) theorizing on how cognitive learning takes place, and the extensive work of Piaget beginning in 1926 describing how children's cognitive operations advance over time, I was taught none of this. I did, however discover the writing of Conant (1947) and his ideas on how the science create new knowledge. Later his protégé, Kuhn (1962) would expand Conant's ideas in his enormously polpular, *The Structure of Scientific Revolutions*. Lacking a psychology of learning that made sense to me, I chose to base my research on Wiener's (1948) *cybernetic* ideas, and we continued with these ideas until our research data failed to fit the theory. Most fortunately Ausubel's (1963) *cognitive* psychology of learning was published about this time, and we embraced this as a foundation from 1963 onward. Today cognitive learning theories have essentially replaced behavioral theories, although much school learning still proceeds on behavioral learning principles, such as repetition and reinforcement.

One of the issues debated in the early 1960's was the extent to which children could profit from instruction on abstract, basic science concepts such as the nature of matter and energy. The dominant thinking in science education and developmental psychology was centered on the work of Jean Piaget (1926), particularly his ideas about cognitive operational stages. Piaget had devised some ingenious interviews administered to children, the results of which could be interpreted to support his theory of stages of cognitive operational development. It was widely assumed that children could not profit from instruction in such abstract concepts as the nature of matter and energy before they reached the formal operational stage of thinking at ages 11 or older.

The fundamental questions that concerned me and my research group were:

1. Are these claimed cognitive operational limitations of children the result of brain development, or are they at least partly an artifact of the kind of schooling and socialization characteristic of Piaget's subjects, and those commonly tested in US and other schools?
2. With appropriate instruction in basic science concepts such as the nature of matter and energy, can six to eight year-old children develop sufficient understanding to influence later learning?
3. Can the development of children's understanding of science concepts be observed as specific changes in their concepts and propositions resulting from the early instruction and from later science instruction?
4. Will the findings in a longitudinal study support the fundamental ideas in Ausubel's (1963) assimilation theory of learning?

Answers to these questions could only be obtained by first designing systematic instruction in basic science concepts for 6-8 year-old children, and then following the same children's understanding of these concepts as they progressed through school, including later grades when formal science courses were taken. This was the instructional development and research project we set out to do.

[1] Based in part on earlier papers, Novak (2004), and Novak (In press).

Development of instructional materials in our longitudinal study was by means of audio-tutorial lessons, in which children learned from audiotapes that we had developed and that were supplemented with film clips and equipment. The audio-tutorial lessons were based on ideas in the National Science Teachers Association report, *Importance of conceptual schemes for science teaching* (Novak, 1964), and an elementary science textbook series, *The World of Science* (Novak, Meister, Knox and Sullivan, 1966).

Figure 1. A six-year old child working with an audio-tutorial lesson dealing with plant growth.

Twenty-eight lessons were developed that dealt with the particulate nature of matter, energy types and energy transformations, energy utilization in living things, and other related ideas. For the most part, these kinds of concepts are rarely presented to elementary school children, especially to 6-8 year olds in grades one and two. Figure 1 shows an example of an early lesson on plant growth. All lessons provided audio-guidance through manipulation of materials in the carrel and other observations, including occasional “loop films” showing animations or time-lapse photography.

The principal principle of the Ausubelian learning theory we considered in the design of our lessons comes from the epigraph to his 1968 book:

> *If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.*

As my graduate students and I developed an idea for a new lesson, we would interview 6-8 primary grade children in an open ended interview, usually using some of the “props” we were planning to use to teach the central concepts of the lesson, such as pictures, materials to be manipulated, loop films or apparatus we were considering. These interviews gave us some idea of what anchoring concepts most of the children already had, and also gave some preliminary feedback on how they were interpreting or using the props. This process was often repeated several times, and again after lesson prototypes were developed. On average, each lesson underwent 6-8 revisions before it was deemed ready to use in classrooms. We also considered Ausubel’s ideas of *progressive differentiation* and *integrative reconciliation* in designing the lessons and lesson sequences (see the section on concept mapping for further discussion of these ideas). The idea of progressive differentiation requires that students build upon their prior relevant concepts, and elaborate concepts in earlier audio-tutorial lessons in a sequence as they study later related lessons. This required that some students needed to experience earlier lessons in a sequence before we could use these students to help develop later lessons. Furthermore, many concepts were revisited in later lessons, but with different examples or props to effect greater differentiation of concepts introduced earlier, and thus also to achieve integrative reconciliation of concepts that may have been initially confusing to a child or where meanings acquired may have been somewhat distorted. Photos and loop films were selected or constructed in many cases to serve as *advance organizers*. That is, we would use things that were familiar to the students, and we would build on the familiar to point them to see new aspects or dimensions of the new materials observed, much of this through the audio guidance.

2 Methodology of the 12-year Study

Ithaca Public Schools had 13 elementary schools, and for logistic reasons we chose to work with first grade teachers in five schools that were representative of the school district. A carrel unit was set up in the corner of the classroom of each of the participating teachers and 191 students in all took turns doing the lessons. These were our experimental or "Instructed" students, so called since very little science is taught in primary grades in Ithaca schools. In the second year of the study, we began to interview 48 students in the same classrooms and with the same teachers as the previous year, but these students did not receive the lessons. This was our control or "Uninstructed" sample. The timeline in Figure 2 shows the sequence of various events in the study that began in 1965 with the development of audio-tutorial lessons and was completed with the publication of the study results in 1991 (Novak and Musonda, 1991).

The lessons were placed in carrel units, usually in a corner of the classroom. The class teacher determined the time provided for student involvement with the lessons, but most often this was during "seat-work" times, or when the teacher was working with small reading groups. Students, one at a time, could take turns doing the audio-tutorial lesson. Some students observed others doing the lessons, and many students repeated lessons one

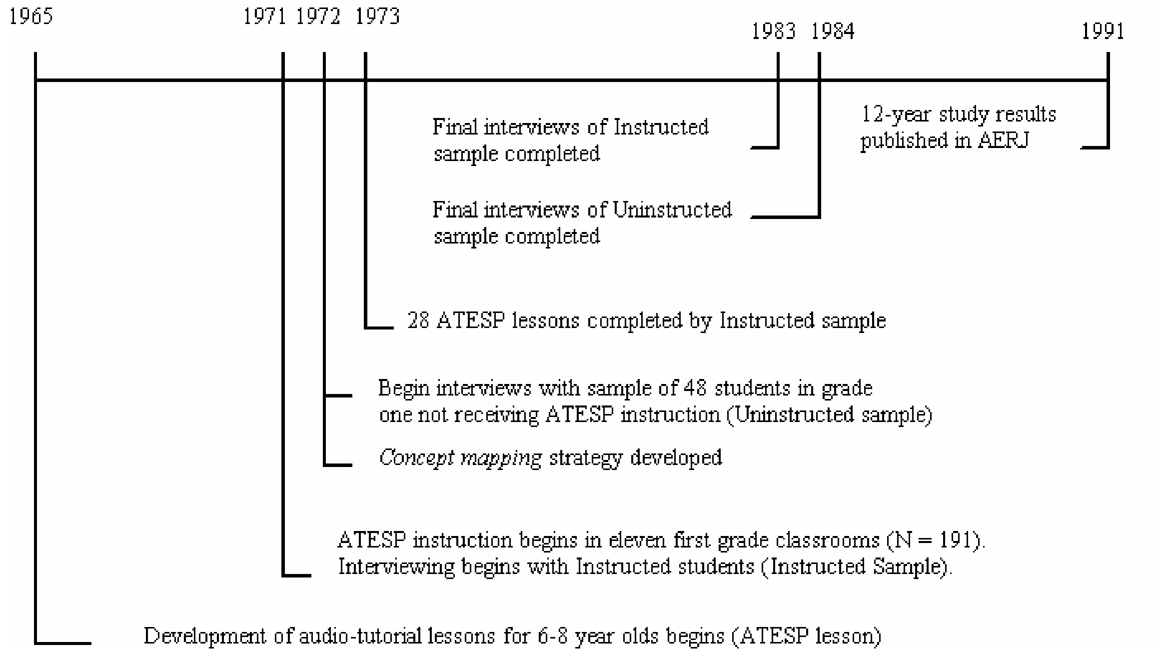

Figure 2: Timeline for the project.
*ATESP: Audio Tutorial Elementary Science Program

or more times, often during recess, lunchtime, or other free time. Each lesson required approximately 20 minutes for a student to complete; thus the 28 lessons provided some 10-20 hours in carefully designed instruction over the two-year span of the instruction. Those teachers who included science in their instruction (a minority) usually dealt with topics such as seasons, clouds, and plant growth, but only in a descriptive manner and not including the basic science concepts such as energy transformations and the particulate nature of matter.

Each teacher we worked with reported excellent student response to the audio-tutorial lessons, and some of the teachers also noted their value for their own learning. None asked to be dropped from the study and most wanted to continue to use the lessons in future years.

Early in the study we developed various forms of paper and pencil tests, including tests with pictures that students marked with crayons following oral questions. We found in subsequent interviews with children that these paper and pencil tests were not valid indicators of the conceptual understanding of students. We subsequently chose to use modified Piagetian interviews as primary evaluation tools, with procedures as described elsewhere (Novak and Gowin, 1984, Ch. 7).

We designed interviews to use some of the materials that were in the lessons and other materials that were different but illustrated the same concepts. We prepared interview kits, and these were used by a number of different graduate students, with some instruction on how to do the interviews. Interviews were done with the Instructed students several times during the first year, including interviews on topics other than the nature of matter and energy. However, we found we did not have the staff resources to continue interviewing all Instructed and Uninstructed students on several domains of science, and chose to interview students only on concepts of matter, energy, and energy transformations. The same interview kits were used as the students progressed through school, and over the years. We also did not have staff to interview all students each year, and we had to choose a random sample from the Instructed and Uninstructed groups for later years of the study. All interviews were tape-recorded and some were also video-recorded. Ithaca has two junior high schools (grades 7-9) and one high school (grades 10-12). This made it easier to do follow-up interviews, especially in their high school years. We made a concerted effort to interview all students remaining in both the Instructed and the Uninstructed samples during their senior year and succeeded in interviewing 85 of the 87 students remaining in high school. Many children have parents who are students at Cornell or Ithaca College, and they leave Ithaca when their parents complete school. With the high attrition rate, we were perhaps a bit lucky that the remaining Instructed and Uninstructed students had almost identical SAT scores, indicating we could consider these samples to be comparable in general ability.

A single investigator could not carry out the large number of interviews, so throughout the project I was assisted by my graduate students. Graduate students do not, however, stay forever. The long period of time meant that over the 13 years of the study (counting the final year of data gathering from the Uninstructed students), 24 different graduate students and staff persons participated in the interviews and interview interpretations. This feature of the study may be unique. I patterned my research group after the models I had come to know as a teaching and research assistant in the Botany Department at the University of Minnesota. Our research group worked with a common, explicit theoretical foundation, we held seminars regularly to discuss out research, our instructional development efforts in several projects in addition to the work reported here, and where we found difficulties in or new insights in our work. This teamwork was essential to maintain the momentum and consistency in methodologies as our work progressed.

3 The Invention of *Concept Mapping*

As we continued interviewing children is our study, we were accumulating hundreds of interview tapes. When we transcribed the tapes, we could observe that propositions used by students would usually improve in relevance, number, and quality, but it was still difficult to observe specifically how their cognitive structures were changing. Our research team considered various alternatives we might explore, and we also reviewed again Ausubel's ideas regarding cognitive development. Three ideas from Ausubel's Assimilation Theory emerged as central to our thinking. First, Ausubel sees the development of new meanings as building on prior relevant concepts and propositions. Second, he sees cognitive structure as organized hierarchically, with more general, more inclusive concepts occupying higher levels in the hierarchy and more specific, less inclusive concepts subsumed under the more general concepts. Third, when meaningful learning occurs, relationships between concepts become more explicit, more precise, and better integrated with other concepts and propositions. The latter involves what Ausubel calls *progressive differentiation* of conceptual and propositional meanings, resulting in more precise and/or more elaborate ideas, and *integrative reconciliation,* or resolution of conflicting or ambiguous meanings or concepts and propositions. In our discussions, the idea developed to translate interview transcripts into a hierarchical structure of concepts and relationships between concepts, i.e., propositions. The ideas developed into the invention of a tool we now call the *concept map*. We now see the development of organized frameworks of knowledge not only the product of meaningful learning, but also the basis for creative thinking and the production of new knowledge (Novak, 1993).

We were somewhat surprised to find that we could rather easily transform the information in an interview transcript into a concept map. Figure 3 shows examples of concept maps we drew from interview transcripts for one above-average Instructed student at the end of grades 2 and 12. Note that while new concepts such as "atom" are assimilated into her cognitive structure, she also has acquired some new misconceptions. This is characteristic of students who learn sometimes by rote and sometimes at relatively low levels of meaningful learning. Figure 4 shows concept maps we drew from interview transcripts with one Uninstructed student at the end of grades 2 and 12. This latter student was obviously disposed to learn meaningfully rather than by rote, and he shows clear evidence of progressive differentiation and integrative reconciliation of his cognitive structure in this domain of knowledge. However, the mean quality of maps for Instructed students was substantially better than for Uninstructed students as will be shown below. We found that a 15-20 page interview transcript could be converted into a one page concept map without losing essential concept and propositional meanings expressed by the interviewee. This we soon realized was a very powerful knowledge representation tool, a tool that would change our research program from this point on.

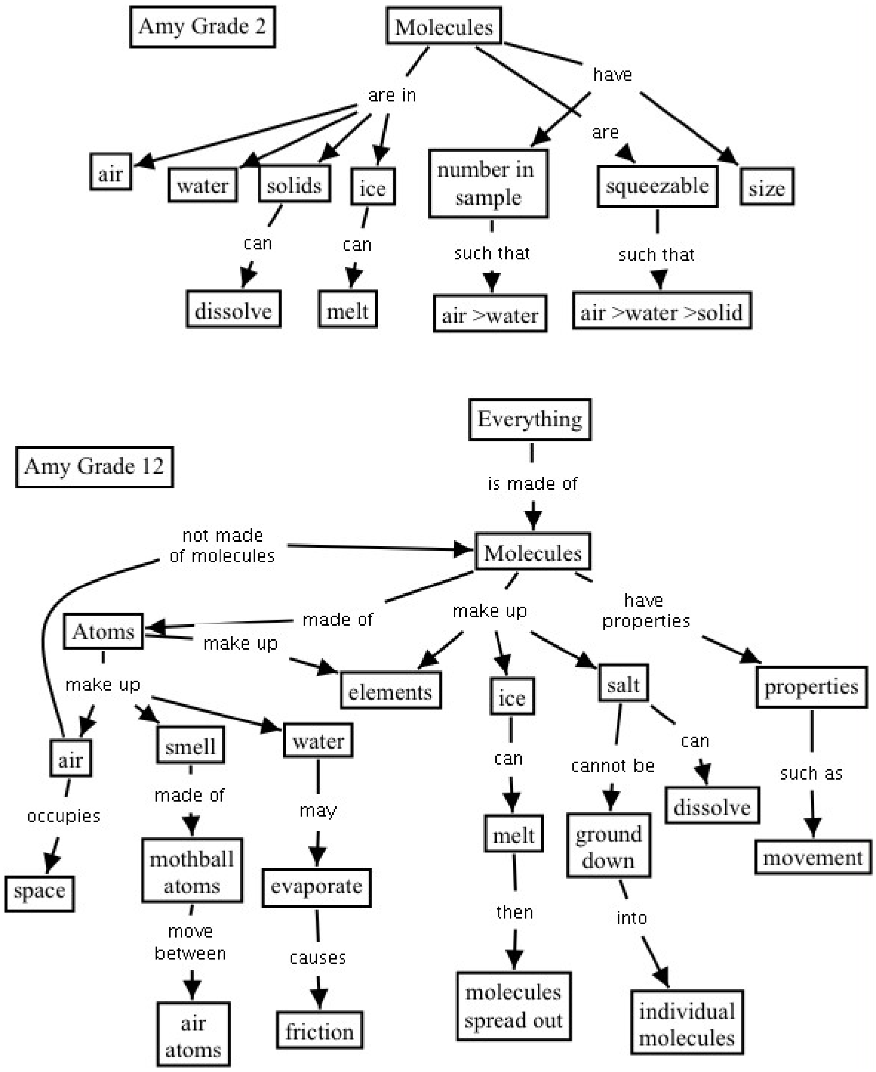

Figure 3: Two concept maps drawn from interviews with an above average Instructed student at the end of grade 2 and at the end of grade 12.

In the history of science, there are many examples where the necessity to develop new tools to observe events or objects led to the development of new technologies. For our research program, the necessity to find a better way to represent children's conceptual understandings and to be able to observe explicit changes in the concept and propositional structures that construct those meanings led to the development of what has now become a powerful knowledge representation tool useful not only in education but in virtually every sector of human activity. It should be noted that although there were other knowledge or semantic structure representations prior to our development of concept maps, most of these are not hierarchically organized, do not contain explicit single concept labels in the "nodes", and usually do not have "linking words" between the concepts that are necessary to represent propositional meanings. Other forms of knowledge representations have been described by Jonassen, Beissner, & Yacci (1993), as well as others.

For our research project, the use of concept maps drawn from structured interviews became the primary tools we used to ascertain what learners know at any point in their educational experience. While it does take an hour or two for an experienced person to make a concept map from a 20-30 minute interview transcript, the precision and clarity of the learner's cognitive structure represented this way made it relatively easy to follow specific changes in the student's knowledge structures as she/he progressed through the grades. We also used concept maps made by our research staff to identify valid and invalid notions held by students. It should be noted that these concept maps were made by many different graduate students over the span of the study, but still the consistency in the patterns observed for each student was remarkable. This illustrates in part the robustness and validity of this form of knowledge representation, as well as consistency in interviewer elicitations over time.

In our study, the researchers constructed the concept maps from the transcripts of the interviews with the children. Later, and not in the study, we got students to construct maps directly, by giving them key terms which they had to arrange in meaningful patterns and then connect with lines that they labeled with the nature of the relation between the terms. When students are taught how to do this direct form of concept mapping, it is possible to use the concept maps they draw to observe the initial state of a learner's knowledge in a given domain, as well as to monitor changes in their cognitive structure. Edwards & Fraser (1983) have shown that students' concept maps can be as revealing of learners' cognitive structures as clinical interviews. We have found student concept maps to be good indicators of their knowledge when learners have sufficient skill in concept mapping and motivation to construct their own concept maps. We did not attempt to have students in our samples construct concept maps, since the training in the use of concept maps was not feasible. While our longitudinal study was in progress, we made little effort to encourage the use of concept maps, since this may have confounded our study results. There were a few of the teachers in Ithaca schools interested in the use of concept maps, but most preferred to continue with their usual teaching practices. As Kinchin (2001) has observed, it is difficult to "fight the system".

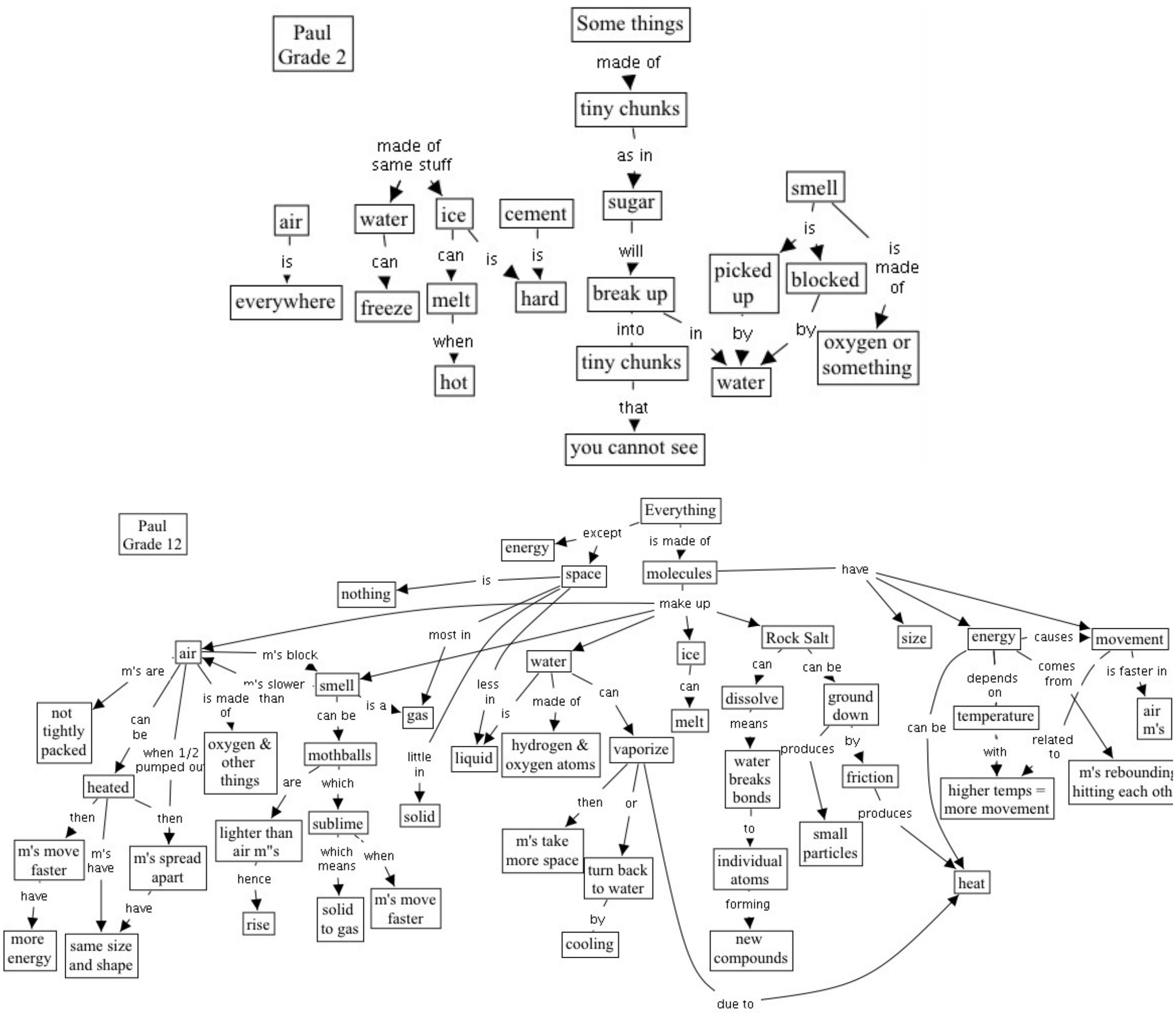

Figure 4.Two concept maps constructed from interviews with an exceptionally good Uninstructed student at the end of grades 2 and 12.

It is important to note that these explicit changes were observed in different interviews done by different graduate students over the span of 12 years. We were careful to have graduate students draw concept maps without knowing whether the interviews were with Instructed or Uninstructed children. The consistency with which the same valid or faulty knowledge structures were shown in concept maps drawn by different researchers illustrates the robustness and reliability of the technique of representing children's understandings in the form of concept maps. Subsequently other investigators have also found concept maps to be reliable, valid indicators of conceptual understanding and changes in relevant concept and propositional structures over time (Ruiz-Primo & Shavelson, 1996; Shavelson & Ruiz-Primo, 2000; Kankkunen, 2001).

4 Major Findings of the Study

Using the concept maps drawn from interviews as the primary source of information, we extracted valid and invalid propositions or notions evidenced in the concept maps. It was clearly evident that Instructed children had fewer and fewer misconceptions as they progressed through school, when compared with Uninstructed students. Conversely, the Instructed students had an increasing number of valid ideas or notions as they progressed through the grades. The results are shown in Figure 5. We see that by the end of grade 2 the Instructed students significantly outperformed the Uninstructed students in their understanding of energy and molecular kinetics ideas. When students begin the formal study of science in grade 7, both Instructed and Uninstructed students improve in their understanding of energy and molecular kinetics concepts, but a highly significant ($p<.001$) superiority of Instructed students compared with Uninstructed students was observed, both for valid and invalid ideas. Moreover, the Instructed students showed steady improvement as they progressed through high school science courses, whereas improvements for Uninstructed students were small. This significant difference in performance over the years for the Instructed and Uninstructed groups led to a significant interaction variance for years in school. Other statistical results have been reported elsewhere (Novak and Musonda, 1991). Clearly the students who were helped to form basic science concepts in grades one and two had developed their cognitive structure (their *subsumers*, in Ausubelian terms) for energy and molecular kinetics ideas in a way that continued to facilitate their meaningful learning, further developing their understandings and reducing their misconceptions. Such remarkable results shout for replication, but to my knowledge, no one else has attempted a 12-year longitudinal study of children's science concept development.

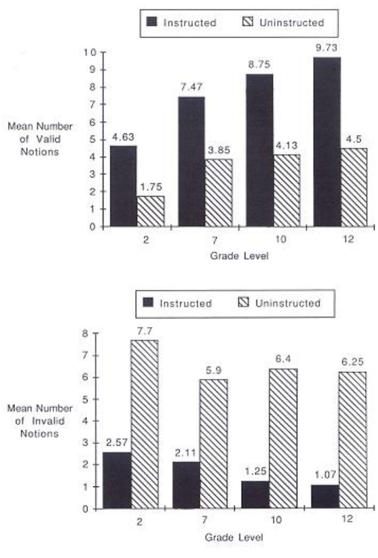

Figure 5: The number of valid and invalid) notions held by Instructed) and Uninstructed) students in grades 2, 7, 10, and 12.

It would appear in retrospect that we were successful with the great efforts we made to devise the right kind of experiences and sequences of experiences in the audio-tutorial lessons, and to provide the necessary concrete-empirical props most of the students needed to acquire the concepts presented meaningfully and substantively. In fact, the data suggest that many of the junior high school science courses failed to do this and hence many of the Uninstructed secondary school students did not progress substantially in their understanding of basic ideas about energy and the structure of matter. Limitations of Piaget's ideas capability of children to develop abstract ideas have been pointed out by others (Cf. Flavell, 1985).

The results reported here and in the published paper (Novak and Musonda, 1991) were initially met with some skepticism, since they fly in the face of the commonly accepted dogma. There remains in the science education literature an overwhelming commitment to the idea that only discovery or inquiry approaches to learning science can result in meaningful learning. Of course, most classroom teachers continue to use lecture and “cook book” laboratories in their teaching, and assessments requiring primarily recall of specifics, with the result that they confirm the limited value of this kind of instruction. What we achieved in our audio-tutorial instruction, and what we propose to do in future projects utilizing computer technologies and the Internet very significantly departs from the common form of classroom science instruction. While my position remains largely a minority position in science education circles, I have every confidence that the validity of the idea that young children can learn to a significant degree basic, abstract science concepts necessary for developing understanding of the wide array of concepts in all of the science disciplines will be validated in the next decade or so, perhaps in Latin countries if not in the USA. One only has to look at where we were in this country for half a century as *behavioral* psychology diminished at best, and prevented at worst, progress in developing a *cognitive* understanding of human learning. We have made great strides in better understanding what is required for science teaching to effect student understanding of science (Mintzes, Wandersee, and Novak, 1998; Bransford, Brown and Cocking, 1999). We have also made progress in identifying better ways to assess student’s understanding of science (Mintzes, Wandersee and Novak, 2000). What is needed now is a new longitudinal study utilizing the latest technological resources to provide the kind of instruction and guidance to teachers and students that could only be done rather crudely with audio-tutorial instruction, albeit the latter was shown to be effective in our work and the work of others (Fisher and MacWhinney, 1976). This new kind of program is described below.

Another significant outcome of the study was to illustrate the power of carefully designed, technologically mediated instruction. While admittedly we dealt with only a limited domain of science, we chose to focus upon the domain of molecular kinetics and energy transformations since this is a notoriously difficult area of instruction in science, especially at the elementary school level. Furthermore, an understanding of these ideas is essential to understanding almost all science phenomena.

5 Development of a New Model of Education

There was in our data strong support for the principal ideas in Ausubel’s Assimilation Theory of cognitive development and general support for the value of cognitive over behavioral psychological theories. Here again the psychological landscape has changed quite dramatically since the 1960’s, with virtually all educational psychologists moving to embrace *cognitive* theories of learning by 1990. In short, the cognitive learning and development ideas that were the foundation of our 12-year longitudinal study are now generally accepted, albeit much of this acceptance was based on hundreds of mostly short term “experiments” done by psychologists and educators, and many of these studies were driven by essentially positivistic epistemological assumptions. Nevertheless, there remains considerable debate in science education circles on the cognitive limitations of young children, and therefore what science should be taught in early grades. In my view, the American Association for the Advancement of Science’s *Benchmarks* (1993) and *Atlas* (2001) and the National Research Council’s *Standards* (1996) grossly underestimate the conceptual learning capability of younger children and unnecessarily and unwisely recommend postponement of instruction in basic energy and molecular kinetics ideas until the middle school years. This precludes the early development of these fundamental concepts needed to understand almost any of the concepts in science, and relegates the early years largely to descriptive studies of biological and physical phenomena. Our 12-year study, and the research of others noted earlier, would argue against postponing instruction in molecular kinetics concepts, as well as other basic science concepts.

Vygotsky (1928 in Russian; 1978 translated) introduced the idea of the “zone of proximal development” (ZPD), implying understandings a child has that can be built upon for further cognitive development. He anticipated Ausubel’s idea that meaningful learning must begin with what the learner already knows. One of the values of concept maps is that when children construct their own concept maps for a question or problem in any domain, they reveal with considerable specificity what is their developmental potential for the topic of study. Thus we are provided with a clear view of “what the learner already knows” and we can design instruction to build upon this. We generally recommend that children build concept maps in small groups, since the exchange that occurs between children can often serve to correct faulty ideas and promote meaningful learning. In part this results from the fact that the cooperating students are at approximately the same level of understanding, much more so than teacher and student. Cooperative learning confers an advantage to students over the usual independent, competitive teaching approaches (Qin, Johnson, & Johnson, 1995; Cañas, Ford, Novak, Hayes, Reichherzer, & Suri, 2001).

Another use of concept maps is to provide maps made by experts to serve to “scaffold” learning of students (O’Donnell, Dansereau & Hall. 2002). The idea of “scaffolding” learning goes back to early studies by Vygotsky where he described his studies showing that language and the social exchange using language can significantly enhance children's cognitive development. Through proper use of language, adults can "scaffold" the learning of concepts by children. Although we were not aware of the scaffolding and ZPD ideas when we designed the audio-tutorial lessons, we were doing things congruent with these ideas. When we were designing our audio-tutorial lessons, we interviewed children to see what their thinking was about a particular concept or problem and then designed experiences that would build on what they knew and would extend their ideas by providing hands-on experiences and appropriate scientific vocabulary to explain the events they were observing. Perhaps one of the reasons the relatively brief instructional experiences children had in audio-tutorial lessons in grades one and two had such a sustained impact on their later learning in sciences was that we were on the right track in working within children's ZPD and using activities and appropriate language to "scaffold" their learning.

Over the years that our longitudinal study was in progress, we became increasingly aware of the extent to which school learning programs lead most students into predominantly rote modes of learning. Some children, for reasons of their genetic make-up or early childhood experiences, resist the effect of school instructional and assessment practices that push students towards rote learning patterns. We have found that interviews and questionnaires can be used to assess individual's proclivities to learn by rote or meaningfully, with most people falling somewhere along a continuum from very rote learners to highly meaningful learners (Edmondson and Novak, 1993; Bretz, 1994). We wish now we had been more aware of the problem of commitment to rote learning and had made assessments of our students in grades one and subsequently of their preferred learning approach. It is likely that such data would have tracked well those students who progressed in their conceptual understandings over the 12 years, and those students who made little progress in their conceptual understanding. While it may be wishful thinking to consider that the audio-tutorial program would have shifted some children's patterns toward meaningful learning, it would have been wise to at least monitor this parameter. I would urge other researchers doing longitudinal studies to monitor their subject's disposition to learn with greater or lesser commitment to meaningful learning.

We have also found in our more recent research that it is useful to assess individuals' commitments to constructivist versus positivistic epistemological views (Edmondson and Novak, 1993; Chang, 1995). In general, we observe that learners who are more constructivist in their epistemological orientation are also more likely to employ meaningful learning strategies than learners who are more positivistic in their orientation. In recent years there has been a large increase in papers published in the *Journal of Research in Science Teaching* dealing with epistemological issues, including a recent paper by Sandoval & Morrison (2003) that deals with the relationship between learning approach and epistemological views held be students. I would urge researchers doing future longitudinal studies to include measures of learner's epistemological ideas, as well as their learning approach.

Audio-tutorial technology is now obsolete, and we have vastly more opportunity to facilitate learning in the sciences as well is in other fields using computer guided instructional strategies and excellent software available for concept mapping, such as the CmapTools (Cañas et al., 2004) software available to schools at no cost from the Institute for Human and Machine Cognition (www.ihmc.us). I see great promise for instructional strategies that combine the use of "expert" concept maps to scaffold student (and teacher) learning using the Internet in conjunction with CmapTools software, inquiry activities and collaborative learning, as I have described elsewhere (Novak, 1998; 2003). These new tools and approaches should provide some very exciting research opportunities for future longitudinal studies that will show the potentials that young minds possess that are not being developed adequately in schools today.

A full discussion on the use of "expert" concept maps to scaffold student and teacher learning using CmapTools with the Internet and related laboratory and field experiences is beyond the scope of this paper. It will be discussed further in the closing lecture for this Conference, titled "Building on New Constructivist Ideas and CmapTools to Create a New Model for Education" (Novak and Cañas, 2004).

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BUILDING ON NEW CONSTRUCTIVIST IDEAS AND CMAPTOOLS TO CREATE A NEW MODEL FOR EDUCATION[1]

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There is today almost universal agreement that every learner must construct her/his own knowledge structure, or cognitive structure, through her/his own efforts. The commitment to building a powerful knowledge structure must be the learner's commitment. There is less universal recognition that knowledge structures are built primarily through *meaningful learning*, and by contrast, rote learning or simply memorizing information contributes little to building a person's knowledge structure. Nevertheless, we believe that Ausubel's theory (1963; 2000) provides a strong foundation on which to improve teaching and learning. We shall seek to illustrate this through efforts that employ constructivist epistemology and constructivist cognitive psychology, together with the use of the Internet and CmapTools, a software toolkit to aid in the construction of concept maps.

1 Introduction

Concept maps have been used in all facets of education and training. Within the fundamental goal of fostering learning (Novak & Gowin, 1984), they have been identified to be an effective tool for –and we don't pretend to provide an exhaustive list– evaluation, displaying students' prior knowledge, summarizing what has been learned, note taking, aiding study, planning, scaffolding for understanding, consolidating educational experiences, improving affective conditions for learning, teaching critical thinking, supporting cooperation and collaboration, and organizing content (Coffey et al., 2003). Aware that *new* technologies have failed to deliver on the false expectation of being the solution to education's problems, we propose that good use of the appropriate technology can increase the benefits of using concept maps in education.

In this paper we first explore the power of CmapTools and how it can support concept mapping, and then discuss how these tools and new ideas can lead to a New Model of Education.

2 The Power of CmapTools

For the past dozen years, the Institute for Human and Machine Cognition (IHMC) has been developing CmapTools (Cañas et al., 2004) a client-server software environment that greatly facilitates the construction and sharing of concept maps. The software is used extensively throughout the world by users of all ages and for a large variety of applications. Describing the complete functionality of the program is beyond the scope of this paper, so we will present some key features that will provide an idea of how the software supports concept mapping.

CmapTools has been designed with the objective of supporting collaboration and sharing. The client-server architecture, together with a collection of Public Places (CmapServers) where any Internet user can create a folder and construct, copy or publish their concept maps, facilitates the sharing of concept maps and the collaboration during concept map construction (Cañas, Hill, Granados, Pérez, & Pérez, 2003). Additionally, a CmapServer (Place) can easily be installed in a classroom or school to facilitate collaboration locally. Collaboration is supported at several levels. If two or more users attempt to edit the same concept map at the same time, the program will –with the consent of the users– establish a synchronous collaboration session where the users can concurrently modify the map and communicate via a chat window. Peer review and collaboration are facilitated through Annotations (post-it notes) that can be added to map after selecting the portion of the map to be annotated, and through Discussion Threads that can be added to a node (concept or linking phrase). When a user creates a folder in a Public Place (server) he/she becomes the Administrator of that folder, and can determine which users receive "annotation" (can comment on a map but cannot modify it, appropriate for peer review), write (can modify the maps, appropriate for teamwork and collaboration) or read-only permissions (appropriate for publishing). In addition, the Knowledge

[1] Based in part on earlier papers, Novak (2004), and Novak (In press).

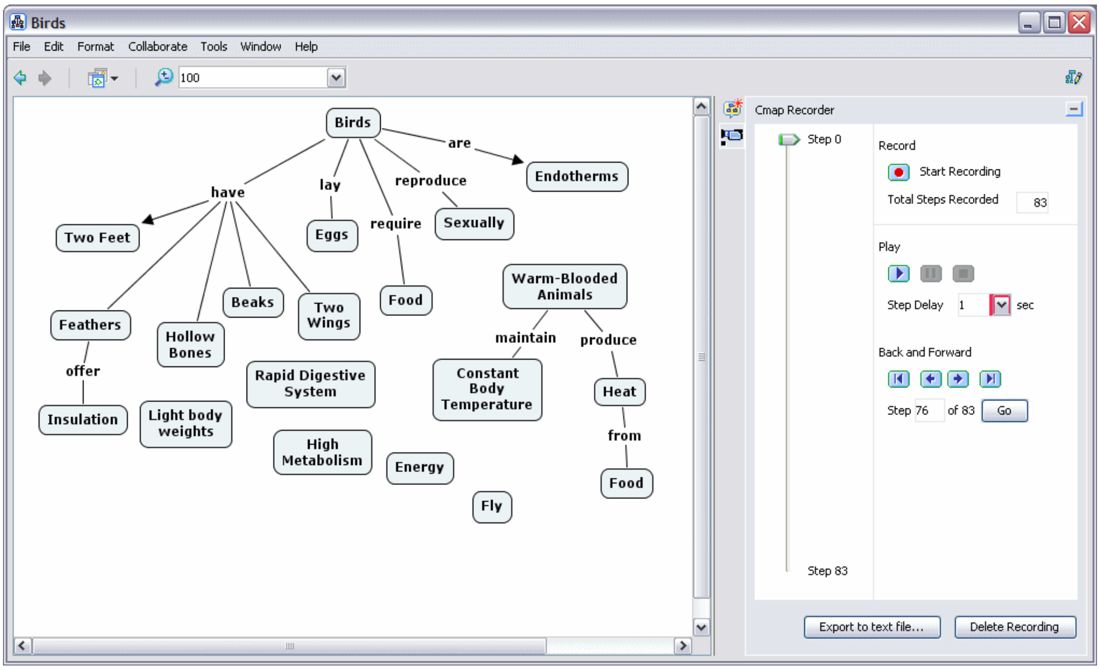

Figure 1. The Recorder feature of CmapTools allows the graphical playback of the steps in the construction of a concept map.

Soups enable collaboration at the proposition or knowledge level (Cañas, Ford, Brennan, Reichherzer, & Hayes, 1995; Cañas et al., 2001)

CmapTools supports the construction of "knowledge models": sets of concept maps and associated resources about a particular topic (Cañas, Hill, & Lott, 2003). Through simple drag-and-drop operations students can link all types of media (images, videos, text, web pages, documents, presentations, etc.) and concept maps, whether theirs or constructed by others, to their maps. These resources can be located anywhere on the Internet.

Novak and Gowin (1984, Chapter 2) have depicted the act of mapping as a creative activity, in which the learner must exert effort to clarify meanings, by identifying important concepts, relationships, and structure within a specified domain of knowledge. Educators have acknowledged that it is the "process" of creating a concept map that is important, not the final product. However, in many cases the teacher can not accompany the students during the process of concept mapping, whether it's because there are too many students, the student is doing the work at home, or the learning is taking place at a distance. CmapTools provides the capability of "recording" the process of constructing a concept map, allowing for a graphical "playback" at a later time, controlling the speed and moving forward or backwards as needed. Figure 1 shows at the right the pane that allows the user to control the recording. In this example, the student has taken 83 steps to reach this point in the map construction, and pressing on the playback button will start showing step by step the complete process of map construction. The recording is saved with the concept map, so if it is copied or moved the recording is not lost. The playback also identifies which user performed each step, which is essential to support collaborative work. We expect that this feature will also provide the capability for researchers to investigate the process followed by different users when constructing concept maps.

Despite the free-style format that concept maps can take, specific characteristics of well-constructed concept maps (structure, semantics, context, etc.) provide an abundance of information on which to develop smart tools that aid the user in the process of constructing concept maps (Cañas & Carvalho, 2004). One such tool allows the user to select a concept in a map and search the web and Places (CmapServers) for information (including concept maps) that is related to the concepts selected, taking into account the context of the concept map itself (Carvalho, Hewett, & Cañas, 2001). That is, the program tries to determine "what the concept map is about" and performs a query accordingly. Researching a topic can begin by constructing a small map and using the search to locate information related to the map. The information retrieved can then be used to improve the map, and the cycle continues. By linking relevant resources found to the map itself, concept the map becomes the centerpiece of the research endeavor.

The program contains other features that support the user, whether a student, teacher, or instructor, in the use of concept mapping in an educational environment, such as a map-comparison module and automatic generation of an HTML version of the concept map when it is stored in a Place. For the purpose of supporting the ideas presented in this paper, we consider that the combination of the collaboration tools, the knowledge model construction features, and the search mechanism provide a strong foundation on which to build the "expert skeleton" map scaffolding ideas in the New Model for Education described in the following sections.

3 Using "Expert skeleton" Concept Maps to "Scaffold" Student and Teacher Learning

During the first author's last 20 years teaching at Cornell University he taught a course called "Learning to Learn". The book, Learning How to Learn (Novak & Gowin, 1984), derived in large part from experiences teaching the course. One of the techniques Novak found most helpful to students was to prepare concept maps showing key ideas and their relationships. These were not complete maps, just the key concepts and relationships. Students were asked to add concepts to the professor's maps and restructure the map in ways that would make the most sense to them. The exams in this course typically provided the students with a list of 20-25 concepts, and they were asked to build a concept map using these concepts and at least 20 additional concepts they wished to add. Students were also asked to select a "learning partner", since considerable research supports the value of cooperative learning (Qin, Johnson, & Johnson, 1995). It was impractical in terms of student schedules to form learning groups larger than two, although sometimes the students took the initiative to meet in groups of 4-6, usually comprising 2-3 learning partner teams. Course evaluations repeatedly commented on the value of the learning partner arrangement, and in fact a few of these led to later marriage of the learning partners. Examples of the kind of concept maps that were used with students can be seen on the CmapTools Network[2].

Novak's experiences in using concept maps to help guide student learning were highly positive. They were supported by Vygotsky's (1928, 1978) ideas of the importance of social exchanges in learning. Another idea that was supported is Vygotsky's concept of "Zone of Proximal Development" (ZPD). Vygotsky's studies showed that there was a level of cognitive development that allowed a learner to advance in understanding of a given domain of knowledge without coaching, and a higher level of understanding beyond which the learner cannot advance without coaching. He called this range of understanding the Zone of proximal Development. One advantage of cooperative learning approaches is that students tend to be at about the same ZPD, hence they can better communicate ideas to each other, and when assisted by "expert skeleton" concept maps, they can progress even further. In general, the literature on "coaching" students using various approaches shows significant facilitation of learning (Bransford, Brown, & Cocking, 1999). Given the learning facilitation now possible using CmapTools, we believe that even greater advantage of Vygotsky's ideas and ideas from the literature on coaching can be incorporated into instruction.

While there needs to be much more research done on how best to devise "expert skeleton" concept maps and how to best employ them in teaching and learning, our experience provides some guidance. For young children, or even older learners, it would be best to begin with very simple expert maps, perhaps not more than five of six concepts. This will be illustrated below in the section on The World of Science Project. The important thing is that the learner must be *active* in acquiring new concepts and building new propositions. CmapTools allows one to access information that is pertinent to the map, but the learner must identify the concepts and construct the new propositions. For younger learners, finding pertinent material that they can understand and can use to select new concepts to incorporate into their map will take patience and guidance. While anyone can drag a new resource onto a concept and "attach" resources to concepts from the Internet or other sources, it takes thinking and new meaning building to isolate the pertinent concepts and construct valid new propositions. This is the central purpose of using "expert" concept maps to scaffold learning. The use of the expert map as a "skeleton" or starting point is important, since it gets the learning off to a valid starting point and serves as a base for selecting new concepts and constructing new propositions. As the learner puts "conceptual meat" on the bones of the skeleton, they are more likely to build a

[2] Place: IHMC Public Cmaps (2), Folder: JDN'sLCKKnowledge.

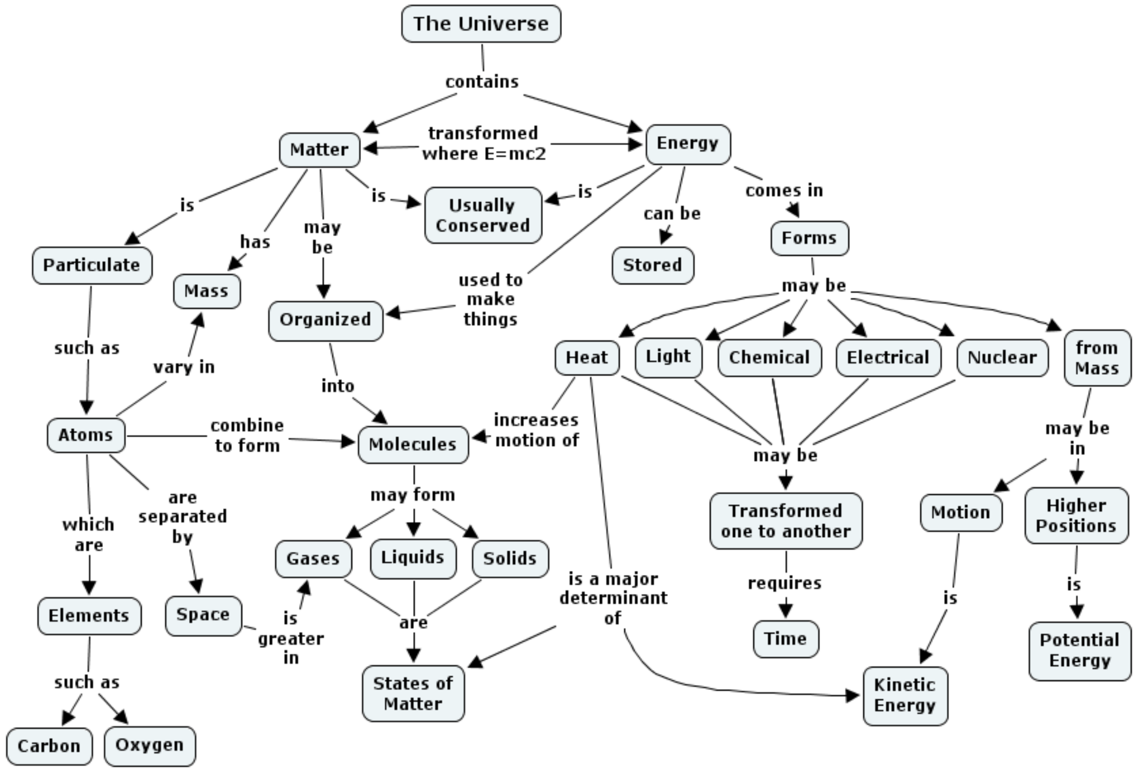

Figure 2. A "global" concept map presenting the major concepts needed to understand most areas of science

solid, valid body of knowledge. This will require hard work and encouragement form the teacher, as well as from peers in a collaboration group.

Our plans are to begin developing "expert skeleton" concept maps in the area of science, since science is universal and it is also a subject poorly taught, especially at the elementary school level. The same could be said for mathematics, and this might be the second area to be developed. We estimate that the project would require some 300 expert concept maps to provide reasonable coverage of all areas of science for grades one through twelve, or ages 6 through 18. There are many scientists who have already prepared concept maps for specific disciplines, so this would be an easy starting point, although many of the maps might need some revisions to make a better fit with the project. Also, we would need to prepare some "global" concept maps to give broad conceptual overview of science or sub-domains of science. Figure 2 is an example of one such "global' concept map. Figure 3 shows a concept map dealing with the kind of energy transformation we call photosynthesis, and could represent a sub-map for Figure 2. Ideally, like this map would be build by a group of cooperating students, and they could also attach pertinent resources to the map. A map of this complexity might be appropriate for 12-15 year old students, although we might expect to see equally complex maps developed by much younger students as they become more expert in the process.

Pérez et al. (Pérez, Suero, Montanero, & Fernández, 2000) report on using concept maps to scaffold university and high school student's learning of physics for more than a decade. Although their students did not use computer software, their feedback indicated better understanding of physics concepts with the use of concept maps. They are now moving towards leveraging on the use of CmapTools and technology (Pérez, Suero, Montanero, & Pardo, 2004). O'Donell, Dansereau, & Hall (2002) report on a study where a kind of concept mapping was used successfully to scaffold learning. A number of other school and university teachers have reported on using scaffolding approaches with concept maps, but little empirical data is available at this time. Therefore, we proceed with this approach with the support of underlying theoretical ideas, and indirect empirical support such as can be found in some of our research (Bascones & Novak, 1985; Novak & Musonda, 1991). The Bascones and Novak

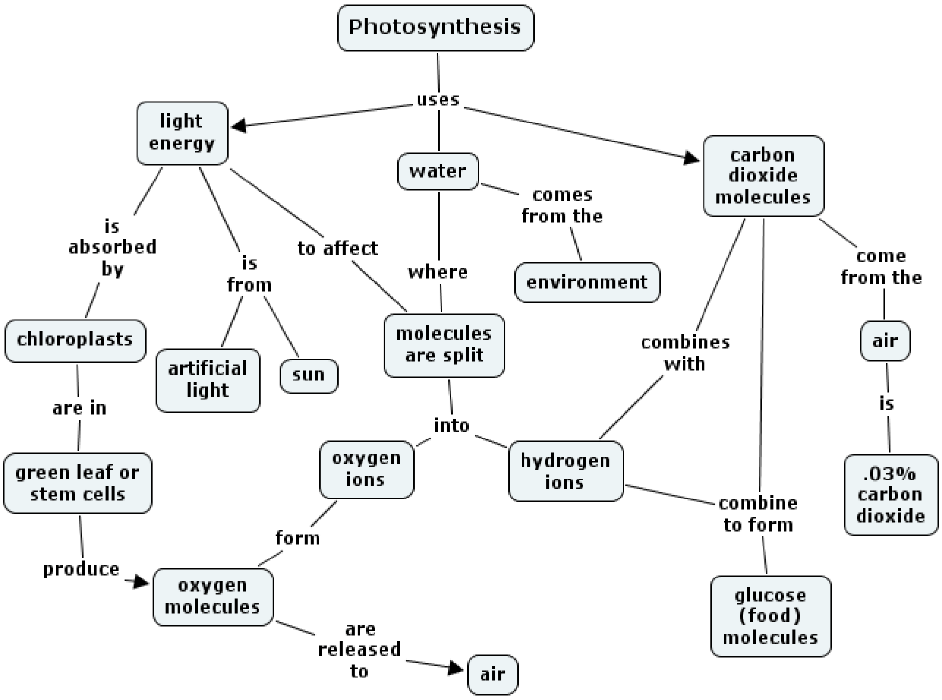

Figure 3. An example of a sub-concept map for Figure 2, dealing with photosynthesis

study showed approximately 100% greater improvement in problem solving scores for high school physics students using concept mapping, compared with students doing traditional exercises. The Novak and Musonda study showed that students taught with audio-tutorial methods in grades one and two achieved 100% or more improvement in understanding of molecular kinetic concepts when compared over twelve school years with students who did not receive this early science instruction. The latter study illustrates in part that technologically mediated instruction can be very effective. The two studies and other similar research show the huge unattained learning improvement potentials that currently exist for the improvement of teaching and learning. No study has looked at the learning improvement that could be attained by applying the best technology and the best pedagogy over the 12-year span of schooling, but the studies that exist suggest that such learning augmentation can approach an order of magnitude greater over a period of years than that now commonly observed.

4 The World of Science Project

During the early 1960's Novak worked on a series of elementary science books that had first been published by Bobbs-Merrill as The Wonderworld of Science, which was a fairly traditional elementary science book series. Most elementary school science textbooks cover many, many topics of science very superficially. None of these books present basic concepts of atoms and molecules and the nature and transformation of energy. Without introducing these concepts, it is essentially impossible to provide explanations of why things in the universe behave as they do. Wonderworld was an apt name for the early Bobbs-Merrill books as well as all other 28 elementary science series that were on the market in the 1960's, and indeed remains the case today! The problem of superficial coverage of science topics was also recognized by the Curriculum Committee of the National Science Teachers Association and their plan to build science instruction on "basic conceptual schemes" (Novak, 1964). Ausubel's cognitive learning theory was published in 1963, and this became a foundation for final writing in the books for The World of Science (Ausubel, 1963, 1968). Novak sought to take many of the good illustrations, activities and ideas in the Wonderworld of Science books and to rewrite the books to include information and activities that would illustrate the particulate nature of matter, energy and energy transformations, and the interplay of energy and matter in living and non-living systems. After 4 years of writing and editing, the *World of Science* was published in 1966. Unfortunately, Bobbs-Merrill was sold to another company in 1968 and this company decided to not market the World of Science books, Nevertheless, the books began to enjoy some success in elementary school classrooms in the USA, and later served as the primary foundation for audio-tutorial lessons designed for our 12-year longitudinal study (Novak, 2004;

Novak & Musonda, 1991). All of these books have now been scanned and we hope to make them publicly available soon at the IHMC web site (www.ihmc.us).

Our plan is to use The World of Science books as a starting point for a demonstration project for A New Model of Education. To begin, concept maps have been prepared for all sections of the grade two book of the World of Science entitled The Exciting World of Science. The concept maps would serve as a starting point for students and teachers for each section illustrated in the book, and then students would use these Cmaps together with CmapTools to search the internet for pertinent resources and ideas. Figure 4 illustrates two of these concept maps dealing with the first sections of the Grade 2 book, pages 6-11 and 12-17, and shows the beginning of how these concept maps might be elaborated by a student, or preferably students working in teams and sharing ideas. All concept maps are publicly available on the CmapTools Network[3]. The science books provide many suggested activities, and it would be important for the teacher to help students perform these activities, and similar related activities, some of which might by suggested in Internet resources. Obviously, it would be a very deficient science program that did nothing more that to have students copy and do some building on the concept maps provided for grade two, or for any other grade. Students need concrete, hands on experiences with real things and to observe real phenomena to put meaning into the concept labels provided in the concept maps and other resources (Novak, In Press). Figure 5 shows concept map showing some of the key features of Novak's New Model of Education. When online, clicking on the icons on

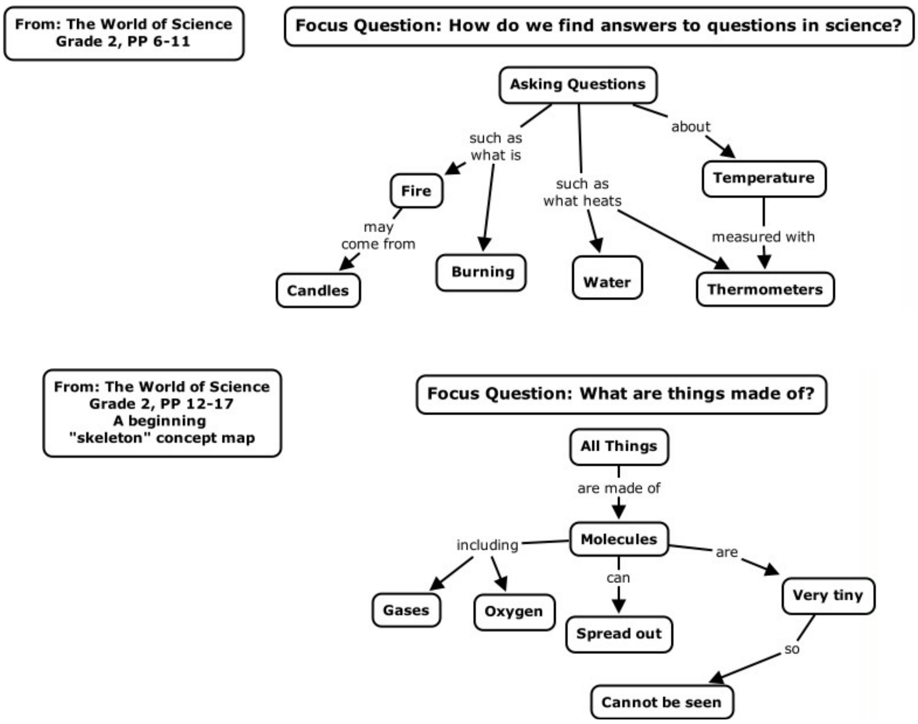

Figure 4. Two sample "skeleton" concept maps for the first sections of Grade 2, The World of Science, pages 6-11 and 12-17.

concepts provides additional information. Other concept maps for the New Model of Education can be found at the CmapTools Network[4].

Pilot program efforts are already in progress in Italy, where Giuseppe Valitutti (2004) is now working to translate The World of Science books into Italian, and Alfredo Tifi and colleagues have started collecting "expert skeleton" maps[5]. We expect a number of elementary school teams to begin working with the World of Science

[3] Place: IHMC Public Cmaps (2), Folder: The World of Science.
[4] Place: IHMC Public Cmaps (2), Folder: Novak's New Model of Education.
[5] CmapTools Network, Place: IHMC Public Cmaps, Folder: LE_PAROLE_DELLA_SCIENZA/ALFREDO.

concept maps and other resources during the next school year, and the feedback should help us to rapidly refine concept maps, techniques and approaches for improving practice of the New Model of Education. The CmapTools

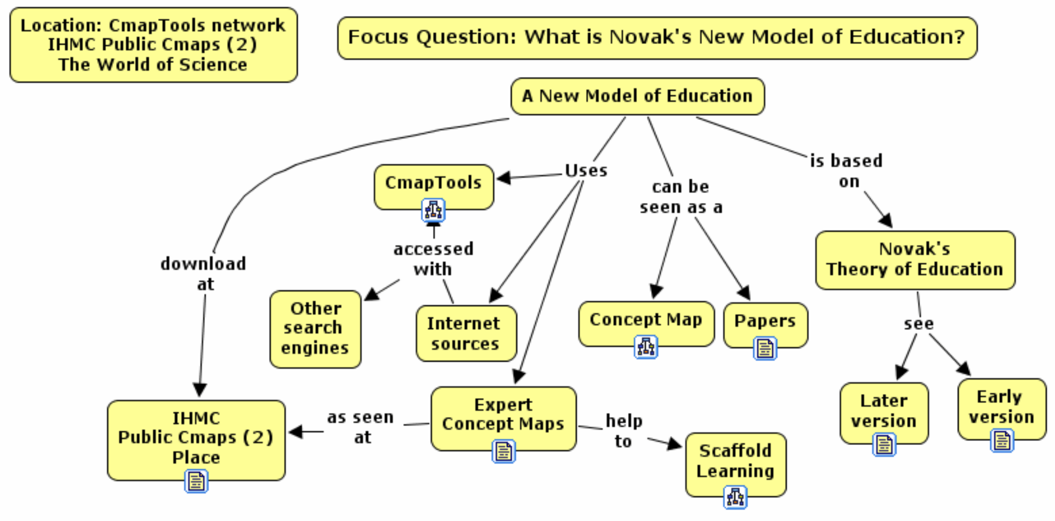

Figure 5. A concept map showing some of the key features of Novak's New Model of Education. When online, the icons below concepts lead to additional information.

Network may serve as a clearing house for some of these efforts, through its Public servers in Italy and other countries. We anticipate that an abundance of both anecdotal and empirical data will flow from these efforts in a few years. Based on the solid theoretical and related research findings now available, there is every reason to be optimistic that these innovative efforts will be successful.

5 Problems of Implementation

The greatest challenge we may expect is to change the school situational factors in the direction of teacher as coach and learner from the prevailing model of teachers as disseminator of information. We know that we need to engage teachers and administrators in training programs that can model the new educational approaches, and we also need to seek their counsel on ways to improve on the New Educational Model. There is also the challenge of changing assessment practices that now rely primarily on multiple-choice tests that measure mainly rote recall of information, to tests that require students to demonstrate that they understand basic concepts and can use these concepts in novel problems solving, and that they can use Internet resources to grow and modify their concepts and learn new concepts. There remains in the New Model plenty of room for acquisition of specific facts and procedures, but now these should be in learned within the context of powerful conceptual frameworks. Research (Bransford et al., 1999) has shown that factual information acquired in a context of meaningful learning is not only retained longer, but they can be used much more successfully to solve new problems.

Even with the current state of technology and pedagogical understandings, it is possible for schools, states or countries to mount a New Model of Education. As technology continues to advance, we should expect that what is relatively expensive and difficult today will become an order of magnitude less costly and more effective in a few years. Furthermore, research on teaching and learning is improving, and this too will contribute to greater effectiveness. The rate and kind of new technological advances is difficult to predict, but the history of the past few decades can serve as a model of where we might expect to be in 10 or 20 years, if we begin to exploit more fully the technologies and ideas available today.

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Pamplona, Spain 2004

TEXT GRAPHS: ACCURATE CONCEPT MAPPING WITH WELL-DEFINED MEANING

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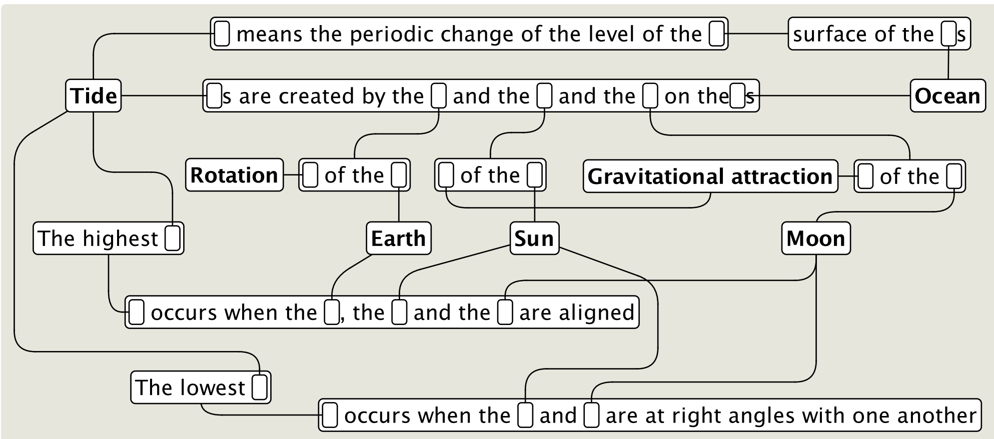
Abstract. Text graphs are special kind of concept maps that can be used in domains where accuracy and well-defined meaning are important. This sort of accuracy is often needed in technical domains like computer science, or whenever a detailed understanding of some complex structural constructions or causal interactions is required. Like traditional concept maps, text graphs are based on few primitive constructs and are thus easy to learn. Unlike traditional concept maps, text graphs allow accurate representation of non-binary relations and relational concepts as well as general propositional information. A text graph can be automatically translated to a set of natural language sentences that people can naturally attach a meaning. The set of sentences is called the text expansion of the graph. The propositional meaning of a text graph – i.e., what the graph asserts about the relationships of concepts - is the same as the meaning of its text expansion. To make text graphs a practical and usable notation, we have developed a text graph editing tool TGE.

1 Introduction

Text documents are *external representations* of the internal conceptual and propositional structures in the author's cognition. When we are reading or producing text, one way to improve the understanding of its content is to use additional externalizations, possibly in some suitable diagrammatic notation, that help us to organize, elaborate, and evaluate the underlying conceptual and propositional structures.

Externalized diagrammatic representations provide the benefits of *distributed cognition* (Hutchins, 1995; Clark, 1997; Norman, 1993): the potentially complex structures need not be kept in the short-term memory but are stored in an external media for later retrieval and modification. In addition, the structures become open to reflection and can be analyzed at a meta-level to reveal the overall structure of the document, the nature of connections, the borders of the topic, and potential gaps in the understanding. As a consequence of such reflection, the understanding of the subject matter hopefully improves and the externalized representation can be reorganized to better suit to the new understanding.

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Tide means the periodic change of the level of the surface of the oceans.
Tides are created by the rotation of the Earth, the gravitational attraction
of the Sun and the gravitational attraction of the Moon on the surface of the
oceans.
The highest tide occurs when the Earth, the Sun and the Moon and aligned.
The lowest tide occurs when the Sun and the Moon are at right angle with one
another.
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Figure 1: A text graph of astronomical tide together with its textual meaning

Bullet lists, mind maps (Buzan, 1974), and concept maps (Novak and Gowin, 1984; Novak, 1998) are examples of widely used representations to support the understanding and production of text. These notations have different properties and consequently are best applicable to different kinds of domains and different stages of processing. Bullet lists and mind maps are more useful in less organized domains and in early stages of processing, such as in note taking or initial sketching of a document. The advantages of concept maps, on the other hand, come in more organized domains and at the later stages of text understanding or production when a more detailed and organized picture needs to be created.

In this paper we describe a variation of concept maps called *text graphs*. Text graphs are best suited for accurate description and definition of complex conceptual and propositional content. Basically, text graphs provide a simple way to split text into fragments and relate these fragments to each other with inclusion relations. Figure 1 contains an example of a text graph that describes concepts related to astronomical tides. Some of the nodes contain points of inclusion, so-called anchors, shown as small rectangles. The box below the figure shows a set of sentences that is the text expansion of the graph. It can be derived automatically from the graph and it helps in determining the meaning of the graph.

In the remaining of the paper we first describe the problems that text graphs are intended to solve, then introduce the basic structures of text graphs, and present the method to derive their propositional meaning. We outline some advanced constructs and their transformations to simple text graphs. Finally we give an overview of a tool called TGE designed for editing and managing text graphs. Throughout the paper we illustrate the uses and properties of text graphs with examples developed using TGE.

2 Background

During the past several years we have successfully used concept maps in our introductory programming courses for first-year university students (Nuutila, Törmä, and Malmi, 2004). Computer programming is a technical area that contains a large number of abstract concepts and mechanisms that novice programmers are not familiar with. To be able to productively use the central mechanisms in computing — such as parameter passing, exceptions, iteration and recursion constructs — a student needs to understand them in a detailed and exact manner.

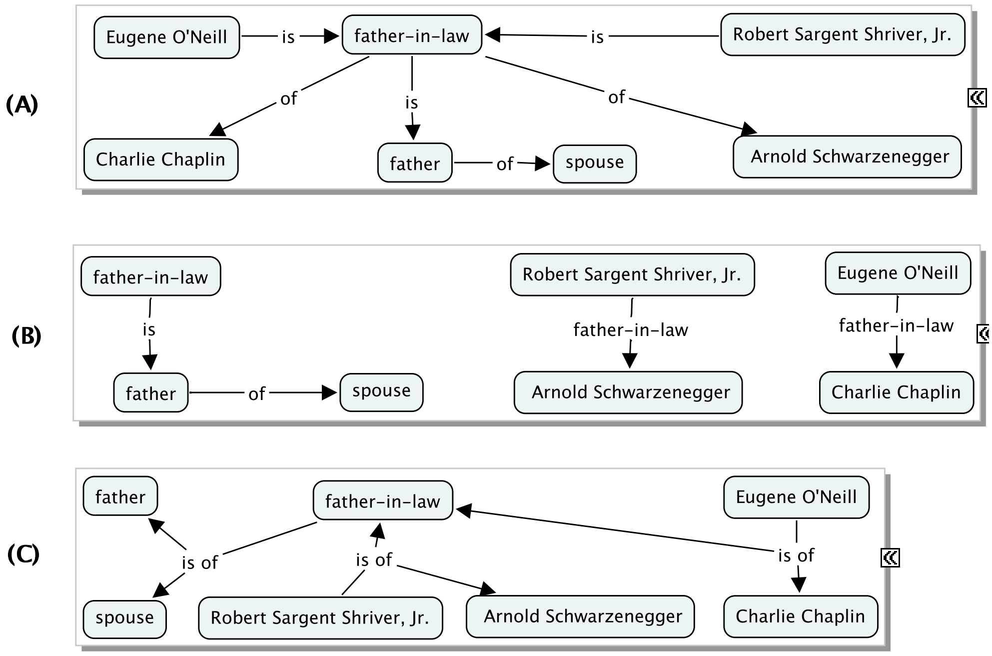


Figure 2: Typical ways of representing a relationship in a concept map

When we have instructed our students in the use of concept maps and studied the maps they produced, we have repeatedly encountered the following kinds of problems in the concept map notation:

- *Ambiguity*. The relations seldom specify uniquely the intended reading. The readers must use their background knowledge and imagination to read a relationship. As a result, different people — and also the author of the map at different points of time — may produce different readings of the same relationship.
- *Binary-only relations*. Fundamentally, concept maps are meant for representation of concepts and *binary* relations between them. In our experience, the attempt to represent other kinds of relations leads to cumbersome or unnatural maps.

- *Concept/relation separation*. The relations can be used to make propositions about concepts, but it is not possible to specify relations that make propositions about other relations in a concept map. This separation between concepts and relations probably makes the use of concept maps easier in simple cases but reduces their applicability to other more advanced uses.

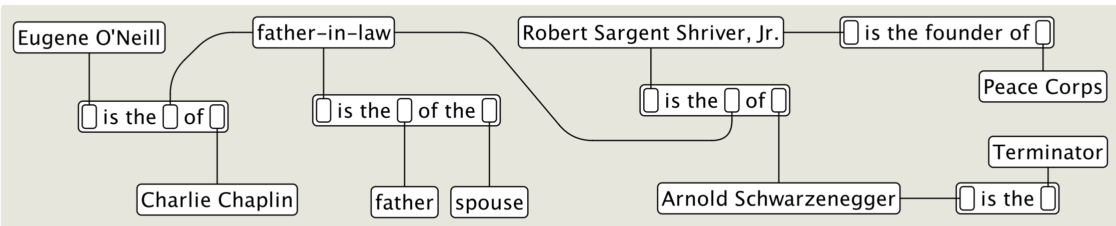
The three concept maps is Figure 2 illustrate these problems. Each map tries to describe a relationship as a concept and give some instances of the use of the relationship. As an example, we use the relationship 'father-in-law', i.e., the father of one's husband or wife (Simpson and Weiner, 1989). In short, we define 'father-in-law' as 'the father of one's spouse'. The examples all illustrate the kinds of concept maps — and also the kinds of flaws — that students in our experience often make.

In map (A), the concept of 'father-in-law' and its instances are neatly connected. However, the map is ambiguous. Without contextual knowledge, we cannot tell whether 'Eugene O'Neill' or 'Robert Sargent Shriver, Jr.' is the father-in-law of 'Arnold Schwarzenegger'.

Map (B) tries to solve this ambiguity by using 'father-in-law' as a link label. The price is that the concept of 'father-in-law' and the instances of 'father-in-law' relationships are now structurally disconnected. In addition, another ambiguity has emerged. Although the arrowheads give the direction of the 'father-in-law' relationships, there are two alternative readings with the opposite meanings: 'X is father-in-law of Y' or 'X has father-in-law who is Y'. The intended meaning should be explicitly stated, but in our experience, the creator of a map if often blind to this kind of ambiguity.

Moreover, in a good concept map, the links should present propositions about concepts. However, the 'of' links in maps (A) and (B) do not present any propositions; they are linguistic constructs. An alternative is to use three-sided links as in map (C). Here the problem is again ambiguity, but it is more severe than in maps (A) and (B): the 'is of' label cannot be replaced with any single label that produces a non-ambiguous reading. The inherent problem is that we try to present a non-binary relation with a fundamentally binary representation.

To solve the problem, we would need a way to order the concepts that are linked and the words in the link label, for example, (1) 'father-in-law' (2) 'is' (3) 'father' (4) 'of' (5) 'spouse'. This is exactly what has been done in the text graph formalism. Figure 3 presents the 'father-in-law' relationship as a text graph (with some additional information) and the resulting text expansion. Here the small boxes — called *anchors* — inside the larger boxes present the order of the connected concepts and text inside the boxes.

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Father-in-law is the father of the spouse.
Eugene O'Neill is the father-in-law of Charlie Chaplin.
Robert Sargent Shriver, Jr. is the father-in-law of Arnold Schwarzenegger.
Robert Sargent Shriver, Jr. is the founder of Peace Corps.
Arnold Schwarzenegger is the Terminator.
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Figure 3: A text graph of father-in-law relationship and its text expansion

Åhlberg (2002) has presented improvements to concept mapping in the same spirit as text graphs. He stresses non-hierarchical nature of knowledge, the importance of accuracy in the labels of concepts and relations, and that each concept should appear only once in a map. One concrete technique is to draw concept nodes inside others that represent more complex concepts. Unfortunately, this is only a partial solution, since a node cannot be inside more than one other node.

3 Basic structures and their meaning

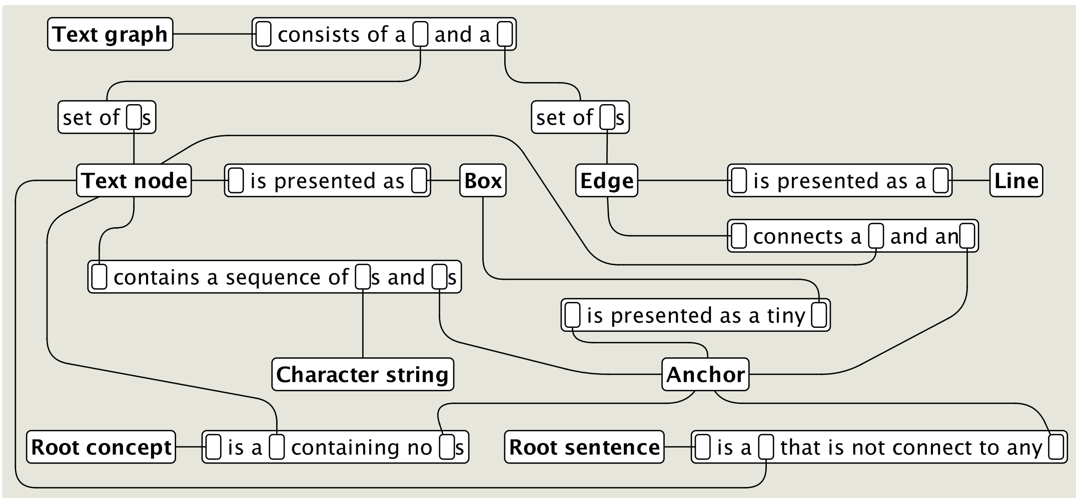
The basic structures of text graphs are described in Figure 4. The central concepts are shown in the bold face font. The box below the figure shows the text expansion of the graph.

Figure 4 identifies two important roles in which the nodes can appear in a text graph: *root concepts* and *root sentences*. The root concepts are simple terms that do not contain anchors. The role of root sentences, on the other hand, is central in the definition of the meaning of a text graph. Root concepts could be thought of as most concept-like and least proposition-like nodes and root sentences as least concept-like and most proposition-like nodes.

It should be noted that there can also be nodes that are neither root concepts nor root sentences, as the "set of" nodes in Figure 4. These nodes are more difficult to characterize. Usually they represent structural concepts, non-independent sentences, or parts of other sentences. Note also that if text graph only contains text nodes without any anchors, they are all both root sentences and root concepts.

A *simple text graph* is one where (1) every anchor is connected to exactly one node and (2) no node path in the graph is cyclic. Node path is a sequence of nodes where node n_2 can follow node n_1 in the path if and only if there is an anchor a in node n_1 and edge e that connects a and n_2. Node path contains a cycle if some node appears two times in the path.

Simple text graphs are not as limited as they may initially appear. Text graphs in Figures 1, 3, 4, and 5 are all simple. Moreover, the first constraint of simple text graphs is lifted below when we describe how general text graphs containing multiply connected anchors can be translated into simple text graphs. The second constraint (no cyclical node paths) is more fundamental and cannot easily be removed. However, it only specifies that certain very rare types of cycles in text graphs are illegal, and does not prevent the description of recursive or inductive structures.

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Text graph consists of a set of Text Nodes and a set of Edges.
Text node contains a sequence of Character strings and Anchors.
Text node is presented as a Box.
Edge connects a Text node and an Anchor.
Edge is presented as a Line.
Anchor is presented as a tiny Box.
Root concept is a Text node containing no Anchors.
Root sentence is a Text node that is not connected to any Anchor.
```

Figure 4: The basic structures of text graphs and the resulting text expansion

Now that the structures of text graphs have been presented, we are faced with the question of the meaning of text graphs. Unless we can give a characterization of their meaning, creating text graphs is little more than drawing pictures that different people can and will interpret in different ways. That would severely limit the usability of text graphs in communication between people.

In the following we will deal separately with the *propositional meaning* (or sentence meaning) and *non-propositional meanings* of text graphs. Propositional meaning concerns what the graph asserts, that is, what propositions it makes. Each proposition has a truth value (true or false) that is the basis for arguing whether the graph makes true or false assertions. Non-propositional meanings deal with what the graph conveys without asserting it. In text graphs it includes the meaning of concepts and the structure of the system of concepts.

The propositional meaning of a simple text graph is specified with respect to the language used in the nodes (note that we do not attempt to specify a formal semantics for text graphs). We define that the *propositional meaning of a simple text graph is the propositional meaning of its text expansion*. A text graph makes all the same assertions than its text expansion and no other assertions beside those.

The text expansion is a string containing expressions in a natural language and its meaning is possibly affected by the interpretation of the people who read it. However, the following can be said:

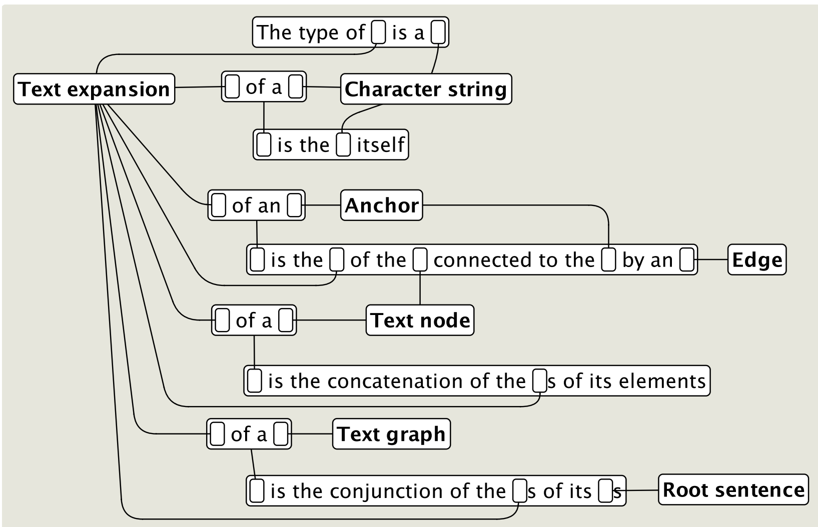
1. The propositional meaning of *two different text graphs* is the same for an *individual reader*, if their text expansions have the same propositional meaning for that reader.
2. The propositional meaning of *one text graph* is the same for *two different readers*, if its text expansion has the same propositional meaning for them.

It should be noted that depending on the text fragments that the nodes of the graph contain, the text expansion can be syntactically malformed, and therefore without any propositional meaning. In addition, it is quite possible to use natural language in a contradictory or ambiguous manner. Since text graphs do not prevent these kinds of uses of language, it is only possible to say that text graphs have a clear propositional meaning when used in a sensible way.

The text expansion of a simple text graph can be derived as specified in Figure 5. These rules rely on the properties of simple text graphs: there is exactly one node connected to each anchor and that graph does not contain cyclical node paths. The text expansion of a text graph is unique, if the order of the sentences produced is not considered relevant.

There are some linguistic issues — such as inclinations, genders, and articles — in the forming of the text expansion, which are outside the scope of this paper.

It can be shown that *every simple text graph has a finite text expansion* (Figure 5). To see this, note that there is a finite number of nodes in the graph and if the graph does not contain cyclical node paths, the text expansion is computed exactly once for each node. (It is interesting to note that Figure 5 is a specification of a recursive function as a text graph.)




```
The type of a Text expansion is a Character string.
Text expansion of a Character string is the Character string itself.
Text expansion of an Anchor is the Text expansion of the Node connected to the
Anchor by an Edge.
Text expansion of a Text node is the concatenation of the Text expansions of
its elements.
Text expansion of Text graph is the conjunction of the Text expansions of its
Root sentences.
```

Figure 5: A text graph describing the text expansion

As stated above, the text expansion helps to determine the *propositional meaning* of a text graph. But why would we want to construct a text graph instead of simply writing the intended text expansion directly? The reason is that there are important *non-propositional meanings* that we want to develop or express with a graph. The central ones concern the meanings of the different concepts in the graph. The graph structure helps us to see what is the *context* of each concept and how each concept is *related to other concepts*. These aspects work as constraints on the possible meanings of the concepts. When the right relations have been specified - a task in which the propositional meaning works as a sanity check - the meaning of the concepts can be greatly clarified.

There are also non-propositional meanings that concern the whole *system of concepts* expressed in the graph: is the graph connected or are there disconnected parts, what are the central concepts (by the number of connections), where the connections seem weak (suggesting poor understanding), and so on. This kind of meta-level analysis can lead into significant clarification of the original concepts and the relationships between concepts and propositions.

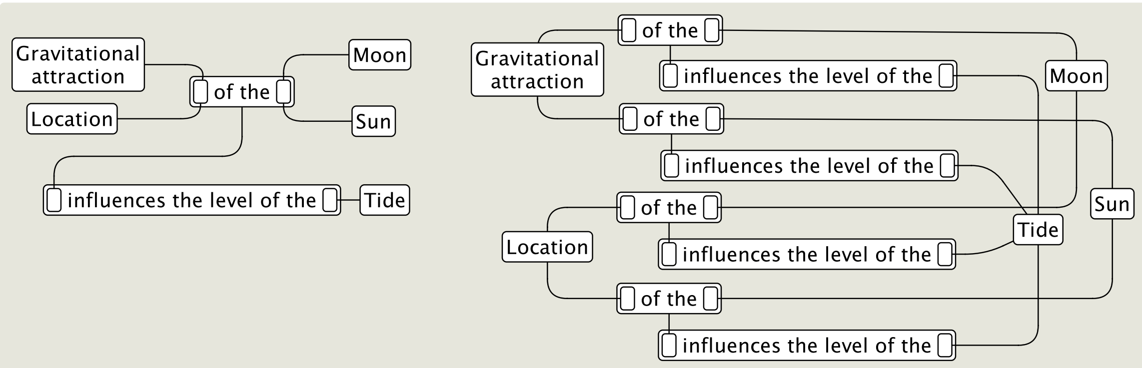
4 Advanced constructs and their transformations

This section describes some advanced constructs of text graphs and how they can be transformed back to simple text graphs. The transformations are needed to specify the meaning of these constructs; it is not suggested, that the author of the graph should carry out these transformations with the graphs he or she is producing. Quite the contrary, these advanced constructs are intended as shorthand notation that simplify the creation of graphs and make them easier to understand.

4.1 Multiply connected anchors

As shorthand it is possible to draw text graphs where anchors are connected to multiple edges. This kind of graphs can always be automatically converted to simple graphs as shown in 6. Therefore the text expansion rules shown above are sufficient to specifying also the meaning of these non-simple cases, as long as the graphs are acyclic.

Figure 6 shows how a node containing two multiply connected anchors (at the left) is split into a set of nodes with singly connected anchors (at the right). The number of resulting singly connected nodes is the size of the Cartesian product of the connections of the anchors in the node.




```
Gravitational attraction of the Sun influences the level of Tide.
Gravitational attraction of the Moon influences the level of Tide.
Location of the Sun influences the level of Tide.
Location of the Moon influences the level of Tide.
```

Figure 6: An example of a multiply connected anchors and resulting simple text graph

When one node is transformed into multiple singly connected nodes (for instance, the “of the” node in the figure), it is possible that other nodes (in this case, the “influences ...” node) get multiply connected anchors as the result. Consequently they have to be multiplied. The transformation thus propagates in the text graph but only toward the root sentences. The root sentences may be multiplied but that does not result in any additional multiply connected anchors (as is the case in the figure). Therefore the propagation always terminates.

4.2 *Subgraphs*

In addition to text nodes, a text graph can contain other text graphs as subgraphs. Figure 7 gives an example where the famous argument from John Locke's Second Treatise of Government is presented inside a subgraph. (Note that the original wording of the argument is somewhat revised to eliminate synonymous phrases.) The content of the subgraph is attributed to John Locke, not the author of the text graph. The author may not want to present the argument in his or her own name since the argument is not logically valid (Fisher, 1988). The central concepts in the argument are presented outside of the subgraph since they are not Locke's inventions.

The subgraph is an ordinary text graph with nodes and anchors connected by edges. However, there are two additional issues. First, the nodes and anchors inside a subgraph can be connected to nodes or anchors outside the subgraph. Second, the subgraph itself can be connected to other nodes or anchors.

The meaning of a subgraph is the text expansion of the conjunction of the root sentences of the subgraph. Consequently, a text graph containing a subgraph can be transformed into a simple text graph by replacing the subgraph with a node that represents a conjunction of the root sentences of the subgraph ("root sentence 1 AND root sentence 2 AND …").

4.3 *Edges between two nodes or two anchors*

An edge between two nodes indicates that the meaning of these nodes is the same. Such an edge can be replaced by a new node "a_1 EQUALS a_2" that contains two anchors a_1 and a_2. First of the anchors is connected to the first node and second to the second node.

An edge between two anchors means that they have the same but unknown meaning. Such an edge can be replaced with a node representing a variable (for example, X) and with two edges from the anchors to that new variable node.

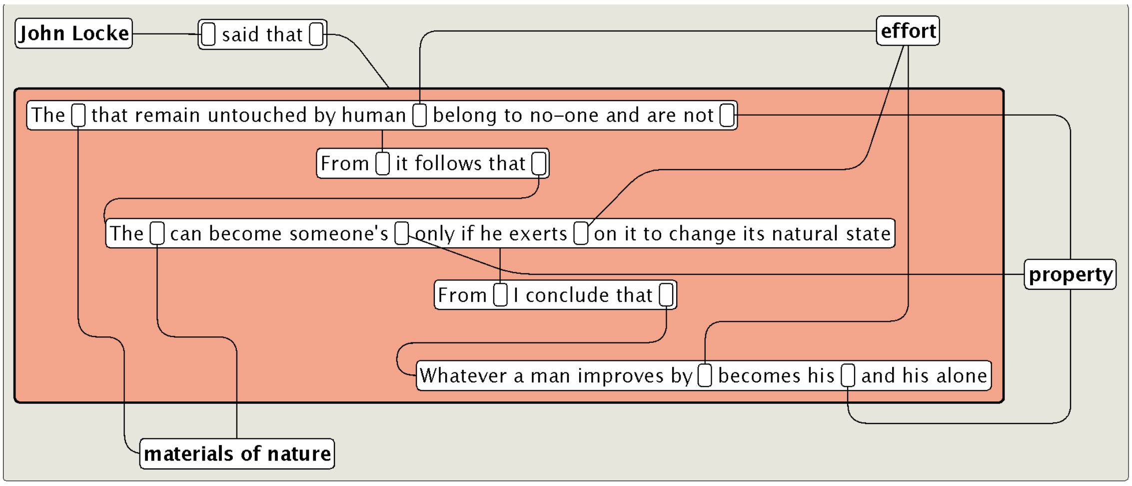


Figure 7: The argument of John Locke presented in a subgraph

5 Text graph tool

Creating a graphical presentation like a text graph by paper and pencil is a tedious task. It is difficult to determine in advance the space requirements and the relative positions of the different parts of the presentation. This problem is greatly magnified when the understanding of the presented structure evolves over the time. The manual labor and the problems with the layout may take most of the capacity of the author.

To enable the authors to pay most of their attention on the conceptual content of the subject matter, a suitable drawing program is a necessity. For concept mapping there is a freely available drawing tool called CmapTools (Novak, 2001), which in our experience is indispensable when working with concept maps. However, it is not completely adequate for text graphs, which require support for fluent editing of mixed content of character strings and anchors, as well as flexible control over the routing of the edges.

To make text graphs a practical and usable notation, we have implemented a text graph editor called TGE. The figures in this paper have been drawn with TGE. The basic capabilities of TGE include node creation and deletion, editing of mixed content of character strings and anchors in an Emacs-like manner, creation and deletion of edges, and moving the graph elements maintaining the topological relations.

More advanced functionality of TGE includes:

- Orthogonality constraints for the edge segments and automatic constraint propagation. This allows the creation and maintenance of edges that consist of orthogonal segments.
- Node and edge styles. All graphical aspects of a nodes and edges can be controlled with styles, including background, line properties, roundings, margins, fonts, etc. In the figures in this paper we have used styles sparingly to focus the attention to the structural properties of text graphs.
- Unlimited undo and redo functionality, and complete logging of the editing operations. In addition of helping the editing task, these capabilities make it easier to have different versions of the same text graph.
- Programming interface that allows the graphs be created programmatically using the Scheme programming language.
- Multiple simultaneous graphical layouts of the text graph. With this functionality, the user can experiment with different layouts for the same graph, while maintaining the topological structure and the textual content of the graph intact.

TGE is implemented in Java. It stores the text graphs and editing logs into Scheme files, and uses Kawa, a free Java-based Scheme system (Bothner, 2003) for processing the Scheme expressions. TGE uses the Qoca constraint solving library (Marriott et al., 1998) for propagation of changes through the graph.

TGE is still in development. The preliminary version that we have is mostly satisfactory. When a sufficiently reliable version has been created, we will make it freely available.

6 Discussion

We have introduced text graphs, a simple notation to represent complex conceptual content. Their goal is to aid human cognitive processing, for instance, in educational settings. The main advantages of text graphs over previous notations with similar goals are accuracy and clear propositional meaning. These properties make text graphs especially suitable for technical domains like computer science. We have also implemented a text graph editor called TGE.

Since a text graph is really just a set of text fragments extended with simple inclusion relations, they can be used for many purposes that ordinary text is used. The nodes can contain any text: concepts, references to individuals, propositions, or questions. When the relations are used in a proper manner, interesting structural information about the text can be made explicit.

Text graphs also suit to different modes of use. There is a correspondence between a text graph and a set of natural language sentences. This correspondence can be used in both directions. On the one hand, an existing text document can be analyzed and a text graph produced to reveal conceptual or propositional structures in the document. On the other hand, a text graph can be produced first and then be used to derive the text that describes the essential structures of the domain. These operations can even be combined: an existing text can be analyzed and a text graph created; then a text expansion is produced as the basis for a text that contains the same information as the original text but is hopefully more explicit and clear.

We intend to use text graph notation and TGE tool in our future computer science courses. We anticipate that this tool will also be used in other domains such as argumentation analysis (Fisher, 1988), knowledge management, development of ontologies, and definition of some diagram types used in computer science and software engineering.

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Pamplona, Spain 2004

MEASURING TEAM COGNITION: CONCEPT MAPPING ELICITATION AS A MEANS OF CONSTRUCTING TEAM SHARED MENTAL MODELS IN AN APPLIED SETTING

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Abstract.—This paper highlights recent research on team cognition and discusses the benefits of concept mapping techniques used in representing shared levels of understanding among team members. Team cognition is comprised of several factors including shared understanding as measured by shared mental models (SMM). To represent team shared mental models more accurately we present a data analysis methodology that utilized individually constructed concept maps as the primary data source. This data is translated into an aggregate map (analysis constructed shared mental model—AC-SMM) that represents team understanding. AC-SMM maps can be compared over a period of time in order to understand the development of team cognition.

1 Introduction

Teams and teamwork are an indispensable part of our society, especially when dealing with difficult, complex, or ill-structured situations, problems, and decision-making tasks not easily addressed by a single individual (Stout, Cannon-Bowers, Salas, & Milanovich, 1999). The benefit of using teams is that each team member contributes to team performance through their individual knowledge/background, specific skills, and particular roles/responsibilities for the team task.

Team cognition has been linked to effective team performance (Orasanu & Salas, 1993; Stout, Cannon-Bowers, & Salas, 1996). However, in order to learn how to improve team cognition and team performance, we need to have an understanding about the teams' development of shared mental models (SMM). One method of measuring mental models is with concept mapping. This method traditionally utilizes the individual as the unit of analysis.

In obtaining a measure of team cognition, we have the option of taking a holistic approach in which team members work together to construct one concept map that represents the team's understanding as a whole. However, the processes of team interaction naturally changes how individuals think. Our intent is to capture the team's shared mental model (SMMi) (see Figure 1). Hence, our alternative in trying to capture the team's SMM is to use individual measures (ICMM) and perform some type of aggregate analysis methods to show team sharedness while retaining individual understanding.

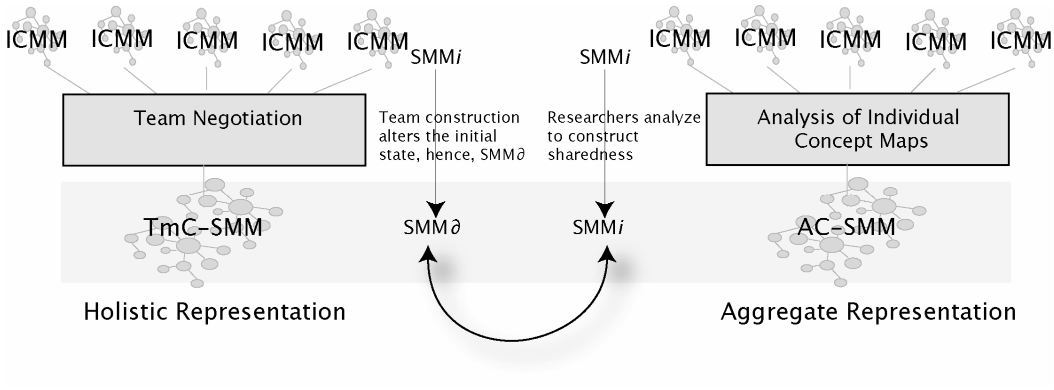

Figure 1. Alternative methods of measuring team shared mental models. ICMM—Individually Constructed Mental Models; SMM*i*—desired shared mental model state; TmC-SMM—Team Constructed Shared Mental Models involving team negotiation and interaction; SMM∂—Altered team shared mental model state; AC-SMM—Analysis Constructed Shared Mental Model that retains the current status of the individually constructed mental models

Langan-Fox, Code, and Langfield-Smith's (2000) review of the literature found that SMM in teams have been investigated by several qualitative and quantitative methods. These methods included different elicitation techniques (e.g., cognitive interviewing, observation, card sorting, causal mapping, pairwise ratings) and representation techniques (e.g., MDS, distance ratio formulas, Pathfinder) that utilize aggregate methods. Each method has various strengths and limitations.

Through concept mapping, similarity of mental models has been measured in terms of the proportion of nodes and links shared between one concept map (mental model) and another (Rowe & Cooke, 1995). Utilizing qualitative techniques with an aggregate method of creating AC-SMM, we hope to capture a more descriptive understanding than that offered by quantitative techniques. Qualitative data analysis tends to offer more detail and depth of information than that which may be found through statistical analyses (Miles & Huberman, 1994; Patton, 2000). Using qualitative analysis, we obtain greater understanding about the relationships between concepts within the context of the individual mental model. We also gain better insight about the sharedness of understanding between team members. In addition, qualitative analysis generates information about the team shared mental model that is not found in an aggregated team shared mental model using only quantitative methods. For example, although we may find that there is a statistically significant relationship between two concepts, the qualitative analysis may reveal information that suggests otherwise. In cases similar to our study, which looked at mental models of team process, qualitative data may reveal inappropriate or inaccurate relationships between concepts.

While there have been many studies conducted using qualitative methods, there are cases where the research setting has constraints such that utilizing various methods are not feasible due to limitations such as time, logistical issues, multiple teams using the same process but focusing on different topics, and the unavailability of necessary data collection instruments. Consequently, utilizing cognitive interviewing, card sorting, computerized elicitation techniques and many other forms of data collection may not be viable options in applied settings.

Because a SMM is potentially different from the sum (aggregate) of individual mental models, and because a holistically created SMM potentially changes individual mental models through the process of creating the holistic SMM representation, we designed a new qualitative analysis technique. This new 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.

If we use these methodologies, we believe that we can better qualitatively represent a team shared mental model thereby facilitating greater understanding of the notion of team cognition and the development of team performance. In comparing the analysis-constructed shared mental model (AC-SMM) at various points during the team process, we should be able to determine how team SMMs change over time. Not only will this information benefit further study in team cognition, but also if we can identify how team SMMs change over time and find indicators of why they changed, we should be able to develop methods for improving overall team performance.

2 Methodologies

Four Performance Improvement teams participated in this study. Each team was newly formed and working in their natural environment on the complex task of revising personnel qualification standards. Team compositions ranged from four to twenty team members. Except for team facilitator(s), team members had background experience and training directly related to the topic of their team task, and most team members had little or no experience with the process involved in performing the team task. Using the common factors between all teams, this study focused on the elicitation of mental models about the process of performing the team task.

In this section, we describe the Analysis Constructed Shared Mental Model methodology for taking team members' individually constructed mental model (ICMM) and using a qualitative analysis technique to construct a representation of the team's shared mental model, or AC-SMM. First, consider the data elicitation methods for construction of the ICMMs.

2.1 Instruments

Prior to data collection, the researchers conducted a task analysis of the process involved in performing the team task. Concepts identified from the task analysis were given to several process experts. These experts were asked to use the concepts in constructing a map to represent their individual understanding of the team task process. Each map was analyzed for key concepts, sequence of concepts, clusters, and concepts identified as being most important to the team task. All experts' concept maps were compared to identify commonalities, or sharedness.

Based on process expert input, three concepts were changed to reflect terminology that was more accurate. This task analysis resulted in an original listing of 22 concepts for study participants to use in creating their ICMMs.

In addition to the listing of key concepts, the lead researcher designed a concept mapping exercise to use during an instructional demonstration with participants. The demonstration focused on how to construct a concept map. Results of pilot testing this exercise showed that the first exercise would take approximately 45 minutes and subsequent repetitions of concept mapping would take 15-20 minutes. Because the results were satisfactory and the exercise took a relatively short period, concept mapping was used as the main form of data collection with all participating teams. Secondary sources of data collection included non-participant researcher observation and audio recordings of teams' work sessions.

2.2 Data Collection Protocol

2.2.1 Concept Maps

To obtain measures for determining change in levels of sharedness between individual team members, concept-mapping exercises were done before the team began working on their task, mid-task, and immediately following task completion. For each concept map, participants were asked to label the concepts they felt were most important and to number any concepts that held a particular sequence.

Prior to the start of the team task, an interactive and instructional demonstration involving all participants was done so that each participant had a brief overview of what was expected during the concept mapping exercises. Although the topic of the demonstration was different from that of the team task, the instruction covered the use of concepts, links, directional links, prepositional phrases, indicators for the most important concepts, and numbers for any concepts that had a particular sequence. Participants were also informed that although they would be given a list of concepts, they were not limited to those concepts and they did not have to use all of the concepts on the list.

Following the concept mapping demonstration, participants were given the list of concepts identified through the task analysis, paper and pens with which to create their concept maps. In addition to these items, participants were reminded that they were not limited to the 22 concepts on the list, but could add concepts they felt were necessary to represent the process of performing their task. Participants were also reminded that they did not have to use all of the concepts presented in the initial list. Each team member was then instructed to create a concept map that represented their understanding about what their team was going to do. All pre-task concept maps were collected by the researcher prior to starting the task.

Midway through the task, team members were asked to construct another concept map that represented their understanding of what they had been doing and what remained to be done. Again, participants were reminded about adding new concepts and not needing to use all concepts provided. Mid-task concept maps were collected from all participants before they continued working on their team task.

A final post-task concept mapping exercise was conducted immediately following completion of the team task. In the final exercise, team members were asked to construct a concept map that represented what their team had done. Instructions for this final exercise also included previous reminders. Final concept maps were collected from the participants before they left.

2.2.2 Supportive Data

Additional data include the task analysis; the analysis of the ICMMs; a comparison of sharedness between the ICMMs, the task analysis, and the actual team task performance; and subsequent analyses of ICMM data. Supportive data also included the non-participant observation notes made by the researcher and audio recordings of the teams' work sessions.

2.3 Data Analysis

Team members individually created concept maps representing their pre-, mid-, and post-task understanding of the team task process. Data obtained from individual team members' ICMMs were used to create an AC-SMM. This section describes the steps taken in analyzing ICMMs.

2.3.1 ICMM Analysis Factors

In order to analyze, compare, and measure a degree of sharedness in ICMMs, we use common factors used in analyzing concept maps such as the number of concepts, links, and node-link-node combinations (Doyle, Radzicki, & Trees, 1998; Jonassen, Reeves, Hong, Harvey, & Peters, 1997; Novak & Gowin, 1984). Additionally, it is necessary to use criteria that are appropriate for the domain (Jonassen, et al.). Because we asked our participants to focus on the process of revising personnel qualification standards as it pertains to their work sessions and not the content within standards, we determined it was better to use causal measures (directional links, sequence of concepts, and clusters) than hierarchical measures and cross-links as suggested by Novak and Gowin.

Analysis of individual maps involved several steps. Before we began data analysis, all data was coded for all participant-added concepts. The same coding scheme was used for all concept maps from each data collection period (pre-, mid-, and post-task). The data from each ICMM were then analyzed in using the following factors.

Factor 1: Concept List—All concepts used in the ICMMs were compiled into a table. Each concept used by a participant is coded. The table includes concepts provided to the participants as well as concepts that are added by participants from the elicitation activity during the data collection phase. In compiling the concept list, each concept is listed only once even if a participant used a concept multiple times.

Factor 2: Sequence—Concepts that are ordered with numbers or letters are coded. Concepts not explicitly ordered are not coded for the sequence factor.

Factor 3: Links—Two or more concepts can be explicitly (clearly stated on the concept map) linked in several ways. Concepts that were linked with arrows are coded as directional links. Single-headed arrows indicate a unidirectional relationship between the connected concepts. Double-headed arrows indicate a bidirectional relationship between concepts. Concepts that are linked with a simple line (without arrows) are coded as non-directional links. These links do not imply a direction.

There are two general types of explicit links: simple and complex (including branch, bracket, and open-end). In each case, the link connector may be a line, a single-headed arrow, or a double-headed arrow. Simple explicit links are just a connector (with or with out arrows) between two concepts. Complex explicit links are minimally two intersecting/shared connectors bridging three or more concepts. These links can include cases where multiple connectors intersect/share in a branch, bracket, or open-end like fashion.

Branch links are minimally a connector that intersects another connector before reaching the next concept. Branched links can also include cases where multiple lines intersect in a hub or cluster-like fashion. A bracket link is a connector that minimally links one concept to a bracket that contains two or more concepts (bracket cluster). In this case (as contrasted with a branch link), a connector only links to a bracket cluster and not the separate concepts within the bracket. Explicit open-end links are connectors that end short of another concept or cluster of concepts.

Factor 4: Important Concepts—Participants were asked to indicate which concepts they felt were most important to their task. Important concepts are noted either by placing a star next to the concept or by listing concepts in order of importance.

Factor 5: Clusters—Next, concept maps are analyzed with the specific objective of combining concepts that are related explicitly and/or implicitly. Implicit relationships primarily focus on concepts that are related spatially. These clusters can include single or hybrid link types (refer to Figure 2, explicit branch cluster).

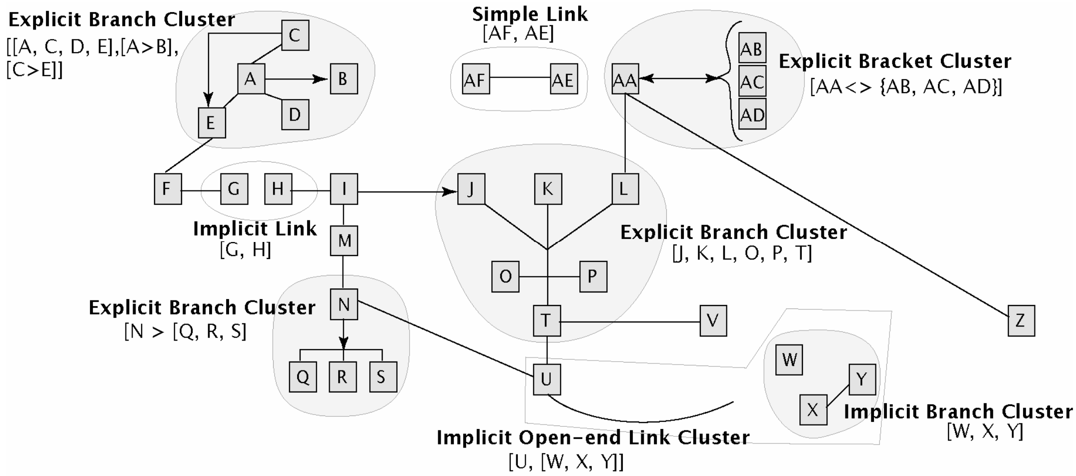

Figure 2. Sample ICMM with coded links and clusters.

When identifying clusters, three key components are considered: spatial information, structural information, and logic information. Spatial information refers to the location of concepts within the map. Interpreting spatial component information requires considering the visual groupings of the concepts as they are presented. Structural information component refers to any type of explicit/implicit links. Valid cluster structures are determined based on cluster concepts all being adjacent to each other or all cluster concepts are all adjacent to a single central concept (in a hub like fashion). The logic information component refers to the conceptual relationship among the concepts in the identified cluster. The conceptual relationship does not have to be complete, but it does have to have logical merit. In identifying clusters, at least two of the three information components need to be present in order to include the cluster in subsequent analysis.

After identifying clusters, examine all clusters from all participants' concept maps for possible sub-clusters. For example, one explicit cluster in Figure 2 contains concepts [N > [Q, R, S]]. It also contains a sub-cluster of [Q, R, S]. Likewise, clusters may be part of larger, more complex super-clusters as found when combining clusters [[A, C, D], [A>B]] and [[C, A, E], [C>E]] resulting in a super-cluster of concepts [[A, C, D, E], [A>B], [C>E]]. Sub- and super-clusters may not have been readily recognized because of their relationship to other components within the individual maps. As with the initially identified clusters, sub- and super-clusters must meet at least two of the three information components to be included in further analysis.

2.3.2 Shared Analysis

Once the ICMM concept maps are analyzed, all of the complex concepts are represented as simple links and simple clusters. Simple links and clusters are then analyzed to show simple sharedness. Complex links and clusters are then analyzed to determine sharedness. The identified simple and complex links and clusters are used as the basic elements for the AC-SMM. Similarities would later be used in the construction of an AC-SMM for each mapping session.

In looking for similarities, all concepts are compared across participants for the mapping session. For all analysis factors, any items that are represented by more than one of the participants are considered shared. Percentage of participants sharing the item is recorded, and the shared factor items are carried forward for use in constructing the AC-SMM.

2.3.3 AC-SMM

The AC-SMM is constructed from the shared ICMM data set. The construction process includes the following five steps. First, all of the shared concepts are listed in the construction area. Second, the clusters are represented and the concepts are adjusted to represent the sequence data. Third, the shared links are added, and fourth, the non-linked concepts are resolved using the original ICMM data as well as secondary data. Lastly, shared important concepts are added.

Step 1: Shared Concepts List—Shared concepts are listed in the construction area. For example, A, B, C, D, E, F, H, and I were identified as shared concepts and each of these elements are included in the initial AC-SMM (Figure 3).

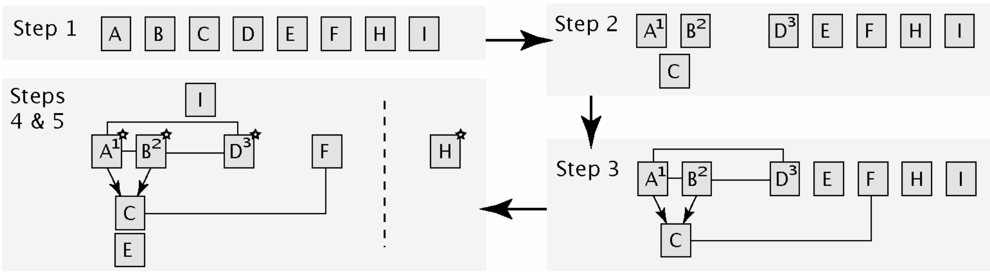

Figure 3. AC-SMM Steps Example

Step 2: Shared Cluster and Sequence Representation—Shared concepts are adjusted to represent the clusters and sequence data. Figure 3 shows only one cluster [[A, B], [A>C], [B>C]] that was shared the participants. Simultaneously, shared sequence data was added to the map. Because concepts A, B, and D were given sequential order by more than one of the participants, these concepts are kept in order from left to right.

Step 3: Shared Links—Shared links are added to the developing shared concept map. Non-directional links [A, D], [A, B], [B, D], and [F, C] are added along with directional links [A>C] and [B>C].

Step 4: Non-linked Concepts—Concepts that are not grouped or related are analyzed using additional data. Specifically, the supporting data includes the original ICMM data as well as secondary data comprised of the initial task analysis (the original listing of concepts used to support interpretation and analysis of pre-task ICMMs) and the ICMM elicitation observation notes. The first consideration in determining placement of unlinked concepts is to see if there are any similarities between participants regarding where the concepts were placed in the ICMMs. If no similarity is found in the ICMMs, then the next step is to check observation notes for data that indicates the concept's relationship to other concepts. If no supporting data are found, then the next step is to check for similarities between concept placements in ICMMs with the location of the concepts in the task analysis. If there is no supporting data indicating where unlinked concepts should be placed in the AC-SMM, then unlinked concepts are separated from the AC-SMM with a vertical dashed line.

In this hypothetical example, we will assume that we found that participant ICMMs showed a similar relationship between concepts C and E even though there were no direct links or clusters. Consequently, unlinked concept E was placed near concept C in the AC-SMM (see Figure 3). Although the ICMMs did not indicate a similarity in placement for either concept H or concept I, observation data from the team task performance indicated a relationship between concepts A, D and I. Therefore, concept I was placed near the non-directional link between concepts A and D. Observation data did not indicate a connection for concept H. After comparing the placement of concept H with the ICMMs, observation data, and the task analysis, there were no similarities found other than the inclusion of concept H. Without specific data to support the placement of concept H, the unlinked concept H is placed outside the concepts represented in the AC-SMM.

Step 5: Shared Important Concepts—Shared important concepts are added to the AC-SMM. In the example, each of the concepts A, B, D, and H were indicated to be the shared important concepts.

The resultant AC-SMM represents the various shared concepts for a team. After the five steps are completed, the shared data is represented in the new map.

3 Discussion

As teams engage in cognitive activities, we would expect to see improvements in individual mental models. In order to show this change, pre and post AC-SMMs would be analyzed to show a comparison between the mental models. This analysis has an emphasis on how things are different rather than the shared focus emphasis that we have described so far. By comparing these differences with other measures such as performance, efficacy, or communication, we can start to understand if indeed the change is related to specific types of cognitive activity.

Based on initial findings?, as teams work together, the similarity among ICMMs tends to increase as does the number of clustered concepts, even though the tendancy is for the number of concepts used to decrease. These factors provide evidence that ICMMs were becoming more structured and more representative of the team task in addition to becoming more similar to the ICMMs of other team members. These ideas are not yet proven. We have designed a set of studies to try and validate our hypothesis. Currently, we are looking at concept maps collected from three content domains: performance improvement (performance standards development), instructional systems (formative evaluation), and science education (mentoring). This work is intended to not only learn about teams that work in the various settings, but to validate the AC-SMM analysis model as delineated in this article.

The use of qualitative analysis we hope provides a richer description of the detail included in the AC-SMM than would have been found with other qualitative and quantitative methods. However, this methodology lacked the weighted measures and precise distances between concepts in the resulting AC-SMM maps as is found in shared maps generated using quantitative methods such as Pathfinder or MDS. Also, as is often the case in concept mapping, there was a lack of prepositional descriptors to define the exact relationship between concepts in ICMMs, requiring the rater to engage in a more exhaustive analysis procedures that are based on other supportive data. In our current studies, we have supportive data from the non-participant researcher observations to support many of these assumptions and decisions. Most importantly, we are in the process of validating the idea that the AC-SMM is a more accurate representation of the SMMi. In addition, we are able to create this shared mental model with minimal disturbance to the team's cognitive activities.

Future steps we are considering include the combination of the AC-SMM methodology with quantitative analysis. This could provide the weighted measures needed for greater precision in the resulting team concept maps in addition to the qualitative descriptions representing fluctuations in team cognition. Once we have a more precise and descriptive analysis of shared mental models, we can utilize the new knowledge to better describe, explain, and understand team cognition. We can also use this deeper understanding about the development of team mental models for determining how to train team members in developing shared mental models. This in turn will facilitate team training with this intent to improve team performance outcomes.

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SYNTHESIZING SOCIAL CONSTRUCTION OF KNOWLEDGE IN ONLINE CONFERENCES USING CONCEPT MAPS

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Abstract. By using content analysis techniques to compare social construction of knowledge in online dialogues to concept maps generated to synthesize this knowledge construction, this study showed that concept maps are an effective tool to synthesize knowledge construction in online conferences. This finding was also supported by self-reported data in a moderator survey. Concept maps were also considered an effective tool for organizing information which indicates that they can be utilized as a knowledge management and preservation tool in online conferences. All students perceived that the Cmap tool software could be used as a tool to foster online collaborative learning in distance education. While it is possible to use concept maps as a collaborative tool, it is important to provide training not only in the use of the software but also on how to collaborate using concept maps in an online environment. In this study, participants were able to generate, save, and post concept maps in the online environment. We also found that students with low technology experience and no previous knowledge of concept maps can learn how to use the tool with a few hours of training and ongoing support during the semester.

1 Introduction

Networked learning facilitated by computer-mediated communication (CMC) using the Internet and the World Wide Web has shown a dramatic increase during the last five years. Research has begun to investigate the effects of CMC on learning and communication among students and between instructors and students. Recently, a number of studies have examined how to design effective online distance learning environments that encourage collaborative learning (Barab & Duffy, 2000; Palincsar & Herrenkohl, 2002; Gunawardena, Jennings, Ortegano-Layne, Frechette, Carabajal, Lindemann & Mummert, 2004). These studies have pointed out the challenges of designing and facilitating collaborative learning which Dillenbourg (1999) defined as learning that takes place in a group setting, where members work together at the same time to construct knowledge, without division of labor. One of the challenges pointed out by research indicates the need to develop instructional strategies and methods that can effectively map and synthesize the vast number and diversity of ideas that are generated during online collaborative learning activities so that groups can engage in the social construction of knowledge.

Coffey and Cañas (2000) affirm that in online distance education, interactive concept maps might be used as learning tools to produce effective learning, especially in learning activities where students in groups can promote the co-construction of knowledge using mapping techniques. Constructivist theory argues that new knowledge should be integrated into existing structures in order to be remembered and be meaningful (Jonassen, 1993). Concept maps simulate this knowledge integration process by making knowledge explicit and by requiring the learner to pay attention to the relationship between concepts (Plotnick, 1997; Gaines & Shaw, 1995). However, only a limited number of studies have looked at concept maps in online collaborative learning environments, and examined the use of concept mapping techniques to solve problems in the distance education context (Kremer & Gaines, 1997; Cañas, et al., 1997; Cañas et al., in press; Stoyanov & Kommers, 1999). Studies have yet to investigate how concept maps can be used to synthesize knowledge construction that occurs in an online collaborative learning environment.

2 The Purpose of This Study and Research Questions

The purpose of this study was to determine whether concept maps can be used to synthesize knowledge construction in online conferences and to determine if the moderators who lead online discussions and use concept maps find them to be a worthwhile tool. Two research questions guided the study: 1) How did the concept maps generated by the moderators to synthesize knowledge construction that occurred in an online text-based conference relate to the actual social construction of knowledge that occurred?; 2) How did the moderators perceive the usefulness of concept maps for: a) synthesizing ideas, b) organizing the group contributions, c) communicating ideas, d) working in collaboration, and e) enhancing collaborative learning in a distance education context.

3 Methods

The study design was predominantly qualitative using in-depth transcript and concept map analysis. We examined online conferences during a semester in order to identify and describe how collaborative concept maps generated by student moderators synthesized the knowledge construction that occurred among class participants in the online text-based conferences. Three sources of data were analyzed: a) computer transcripts generated by the online community while participating in discussions moderated by small groups of students, b) concept maps generated by the student moderators to synthesize knowledge construction that occurred in the discussions, and c) an online moderator survey soliciting student moderator opinions on the use of concept maps.

3.1 Participants

The subjects for this study were fourteen students enrolled in a graduate course on the theory and practice of distance education at a Southwestern University in the United States, during the Fall 2003 semester. The majority of the group (71%) did not have previous experience in concept maps and they were not familiar with software that generates concept maps. Twenty six percent knew what a concept map was but had never generated one. Those same 26% knew about Inspiration software but only one (6%) knew how to use it.

3.2 Instruments and Data Analysis

In order to answer the first research question, text transcripts of three two-week long computer conferences were compared with concept maps generated by moderators of these three conferences . The text-based computer transcripts were analyzed using the Gunawardena, Lowe and Anderson (1997) five phase model of content analysis that describes steps in the social construction of knowledge. The phases are: I. Sharing/Comparing of Information; II. The discovery and exploration of dissonance or inconsistency among ideas, concepts or statements; III. Negotiation of meaning/co-construction of knowledge; IV. Testing and modification of proposed synthesis or co-construction; and V. Agreement statement(s)/applications of newly constructed meaning. The unit of analysis was the message. Sometimes one message was assigned two codes, because we observed that one unit contains more than one meaning that contributes to the co-construction of knowledge. Three codes were added to the five phase model to reflect a) socio-affective statements that seemed to offer the motivation for knowledge construction that predominantly occurred in Phase I, b) statements based on authors' ideas paraphrasing and/or using citations coded in Phase I, and c) elaborations and reflections based on participants' own or authors' ideas that occurred predominantly in Phase II. The content analysis method identified strategies that the group used during the social construction of knowledge, and examined the negotiation of meaning that occurred in the online conferences. Concept map propositions were compared with the categories that emerged from the transcript analysis to determine how the maps generated showed the social construction of knowledge that occurred. Trustworthiness and confirmability were established through a verification process with participants using the responses to a moderator survey. Thus, data was triangulated using the categories that emerged from the transcript analysis, the concept map propositions, and the moderator survey.

In order to answer the second research question, data was gathered from an online moderator survey administered after the groups had finished their roles as moderators. Content validity of the survey was determined by using an expert's judgment on each survey item. The expert was a researcher with more than 12 years of experience in distance education. The online survey administered via the WebCT platform consisted of five open-ended questions. Its purpose was to obtain self-reported information about students' experiences using concept maps to organize, communicate, and work collaboratively in summarizing the knowledge construction that occurred in the online discussion that they moderated. Content analysis using the qualitative analysis software package ATLASti v.4.2 was used to derive categories and codes from the moderator self reports. The results obtained from research questions one and two were triangulated to identify correspondence between transcript analyses, concept maps and the moderators' survey results. The triangulation method would identify the usefulness of using concept maps to synthesize group ideas as well as allow us to determine if students were able to develop concept maps in a group to organize and communicate ideas, work in collaboration, and enhance collaborative learning in distance education.

3.3 Procedures

Before beginning the study, the online course was designed using the WebCT learning management system based on a community of practice instructional design model called the Final Outcome Centered Around Learner (FOCAL) model (Gunawardena et al., 2004). FOCAL is a model based on constructivist and socioconstructivist paradigms and distance education principles for the design of online wisdom communities. FOCAL focuses on the process of learning as well as the product. This instructional design model supports the idea that all learners will socially construct their knowledge by interaction with each other in an online social context. In two face-to-face classes at the beginning of the semester, all students were trained on concept mapping techniques using CmapTools v.3 software (Cañas *et al*., 2003). The software was created and developed by the Institute for Human and Machine Cognition (IHMC). This software has been licensed by IHMC UWF in a free Beta version and was provided for educational and non-profit use only. CmapTools empowers users to construct, navigate, share, and criticize knowledge models represented as concept maps. The tools are platform-independent and network-enabled, allowing the users to build and collaborate during the construction of concept maps with colleagues anywhere on the network, and share and navigate through others' models distributed on servers throughout the Internet (IHMC, 2003). Student moderators who were responsible for conducting the discussions were required to post a narrative summary of the discussion and a concept map synthesizing the knowledge construction that occurred during the discussion that they moderated.

4 Results and Discussion

4.1 Research Question 1

The first research question examined how the concept maps generated by student moderators to synthesize knowledge construction related to the actual social construction of knowledge that occurred. A total of five computer conferences were moderated by groups of students. From those, three conferences were selected and analyzed. The computer conferences selected were: 1) Transactional Distance, because it was the first computer conference moderated by students; 2) Social Presence, because it was conducted at the middle term of the semester; and 3) Learner Support, because it was the final conference in the semester. The decision to choose conferences based on the time they occurred during the course of the semester was because we theorized that the social construction of knowledge was different at different times during the semester. We hypothesized that because time must be a variable that influences the groups' cohesion, close relationships and familiarity between group members would increase over time and affect the co-construction of knowledge.

4.1.1 Computer conference: Transactional Distance

Transactional Distance was the first conference moderated by a group of three students. Table 1 indicates the results from the analysis of the computer transcript to determine knowledge construction. It can be seen that the majority of messages during the two weeks are located in Phase I, the sharing and comparing of information. It was observed that the moderators used questioning techniques which caused the whole group to 'ask and answer questions' in a pattern of interaction. Table 1 shows the presence of many socio-affective behaviors during the first week and a decline of these in the second week (from 28 to 12). It appears as though there was a need for the group to build the appropriate social environment before they could begin discussing issues related to the topic and engage in knowledge construction. During the second week students questioned less and demonstrated more negotiation skills. Table I also indicates that there were a considerable number of messages in Phase III, the negotiation of meaning and co-construction of knowledge.

Phases	Codes	Week 1	Week 2	Totals
I. Sharing/ Comparing of Information	PhI/A	8	10	18
	PhI/B	10	4	14
	PhI/C	0	1	1
	PhI/D	30	18	48
	PhI/E	6	0	6
* Socio affective/share personal experiences	PhI/F	28	12	40
* Statements based on authors' ideas	PhI/G	4	1	5
II. The discovery and exploration of dissonance or inconsistency among Ideas	PhII/A	1	1	2
	PhII/B	0	0	0
	PhII/C	0	2	2
* Elaborations based on participants or authors ideas	PhII/D	0	2	3
III. Negotiation of meaning/co-construction of knowledge	PhIII/A	0	7	7
	PhIII/B	1	3	4
	PhIII/C	0	3	3
	PhIII/D	5	3	8
	PhIII/E	3	4	7
IV. Testing and modification of	PhIV/A	0	0	0

Proposed synthesis or co-construction	PhIV/B	4	2	6
	PhIV/C	6	12	18
	PhIV/D	0	0	0
	PhIV/E	0	2	2
V. Agreement statements(s)/ application of newly constructed meaning	PhV/A	6	10	16
	PhV/B	1	1	2
	PhV/C	0	10	10
Totals		113	108	222

Table 1: Social construction of knowledge on Transactional Distance

In order to compare if the moderators were able to summarize the social construction of knowledge that occurred in a computer conference, all messages that fell into phases III, IV and V of the model were identified and extracted. Correspondence between the knowledge socially constructed in the computer conference and the concepts and propositions used by the moderators to summarize the knowledge construction that occurred using a concept map are shown in Table 2. The correspondence between the concepts and propositions in the transcript, and the concepts and propositions generated in the concept map are indicated by numbers in the concept map see Figure 1.

Phase	Concepts and propositions in the text-based transcript		Concepts and propositions in the concept map
Ph4/C	Transactional distance (TD) could be decreased when learners and instructors look for the balance between dialogue and structure	1 & 2	TD in a DE community of learners involves a balance of: Structure and Dialogue
Ph4/C	The course design imposes some structure in term of assignments to complete but the learners have some flexibility to choose what to learn	3	Structure includes Flexibility
Ph4/C	Time is an important determining factor in the relationship between structure and dialogue. While time is passing the learner will increase dialogue and the course structure should be perceived as less rigid	4	Structure includes time
Ph3/A	TD depends on the familiarly with the medium, once the learner becomes familiar with the interface and the medium it will lead to a decrease in the perceived course structure.	5	Structure includes Medium

Table 2: Example of correspondence between concepts and propositions used in the concept map to summarize the text-based discussion on: Transactional distance and control

Figure 1 shows the concept map generated by this group. The analysis of this concept map indicated that all nodes represented were conceptually emphasized and generated by the online group. This group classified their concepts using color to facilitate the visualization of the diverse concepts that emerged from the main concepts discussed. As observed in the map, these main concepts were bolded and represented in various shapes to easily differentiate them from the sub-concepts derived from the main ones. As observed from the map and from the content analysis of the transcript, four main concepts were discussed: structure (1), dialogue (2), autonomy (11) and control (15). Throughout the discussion it was noted that the main emphasis was on the negotiation about how these issues needed to be balanced and planned in order to decrease or lessen the transactional distance. However, this group did not use the necessary links and linkwords to represent the complexity of the knowledge socially constructed by the group. As a result, the map appeared very simplistic in comparison with the propositions found in the transcripts. It appeared that the group put the most effort in representing the main concepts and grouping ideas under each main concept represented.

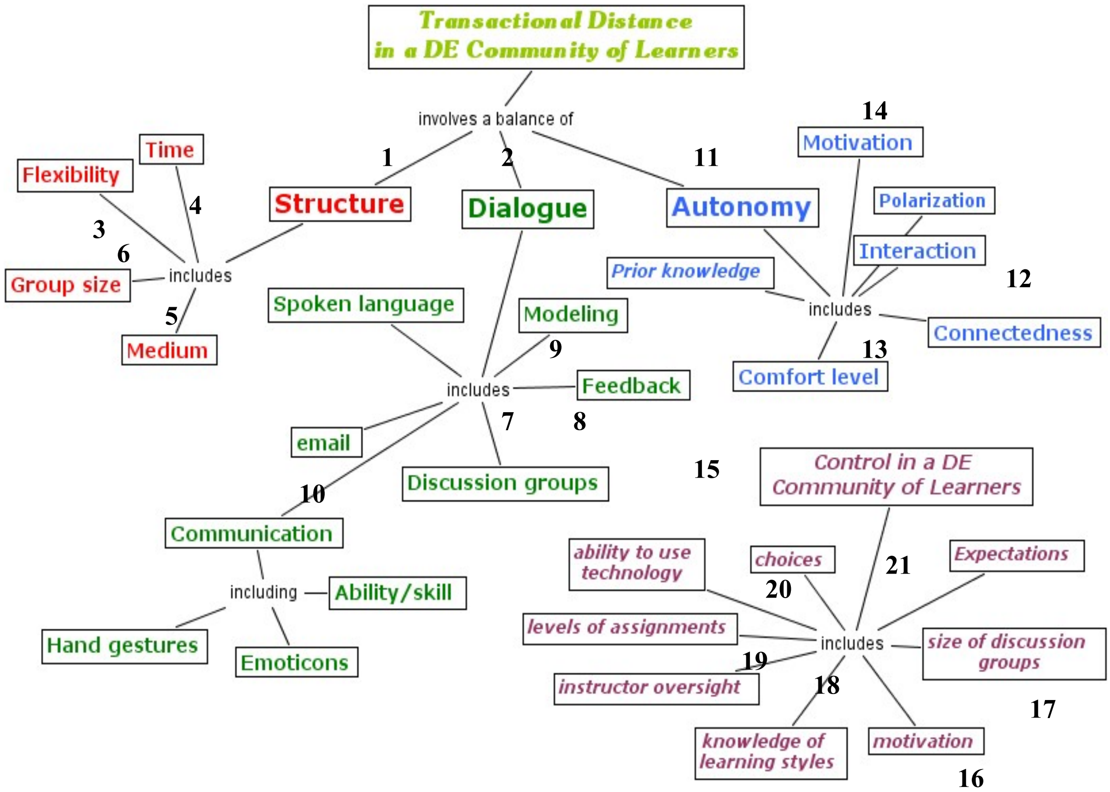

Figure 1. Concept map synthesizing social construction of knowledge in the Transactional Distance computer conference

4.1.2 Computer conference: Social Presence

The conference entitled "Social Presence" was moderated by three students. This group decided to implement a different format for the computer discussion. They divided the group into three subgroups of four participants randomly assigning students to each group. Each member of the moderating group took the responsibility of moderating a small group under the same conditions, i.e., using the same set of questions and communication strategies. A total of 141 messages were generated in the three groups. In order to determine if the moderators summarized the social construction of knowledge that occurred using a concept map, results from the content analysis of the computer transcript were compared with the propositions generated in the concept map. The lists of concepts and propositions that were generated in phases III to V, and the propositions in the concept maps that corresponded to these propositions, are contained in Table 3. Proposition numbers in Table 3 correspond to those numbers found in the concept map in Figure 2, and both the table and figure should be read together.

The collaborative generation of the concept map allowed this group to extend the social construction of knowledge to the importance of using an icebreaker to create social presence, and its close relationship with cultural issues in an online environment. This extension was incorporated into their concept map, suggesting that cultural issues that cross cultural boundaries could be used as icebreakers, e.g. using sounds, food, recipe exchanges, family, last vacation, among others already mentioned. Another extension was the connection made by relating cultural issues with what is considered personal; a normal degree of self-disclosure. The final extension showed that cultural issues need to be considered when using use icebreakers and that certain topics such as social status, religion, politics, and sports, must be avoided.

In general, the map summarized and synthesized the knowledge constructed by the three subgroups. The construction of this concept map was a more complex activity than the first concept map as three discussions were synthesized in one concept map. Group 2 also showed the extension of ideas related to culture while creating the concept map, thereby sharing that the collaborative construction of a concept map can extend knowledge construction in computer conferences.

Phase	Concepts and propositions in the transcripts		Concepts and propositions in the concept map
Ph4/C			
	4.2 Strategies to generate social presence	1	Social presence attempted to create with an icebreaker
	Icebreakers are important at the beginning and through the course to generate social presence	2	Icebreaker created SP? Yes, especially at the beginning
		3	But also throughout the course
Ph4/C	Types of icebreakers		
		4	Icebreaker brought up cultural issues (extension)
		5	Moderators provided suggestions for icebreakers that cross-cultural boundaries: (extension)
Ph5/B			
	Pet/animals stories	6	Pet/animals stories
	Sound	7	Sound
	Food (favorites, recipes)	8	Food (favorites, recipes)
	Photos	9	Photos
	Family	10	Family
	Last vacation	11	Last vacation
	Jokes	12	Jokes
	Special moment	13	Special moment
	backgrounds	14	backgrounds

Table 3: Example of correspondence between concepts and propositions used in the concept map to summarize the computer conference: Social presence

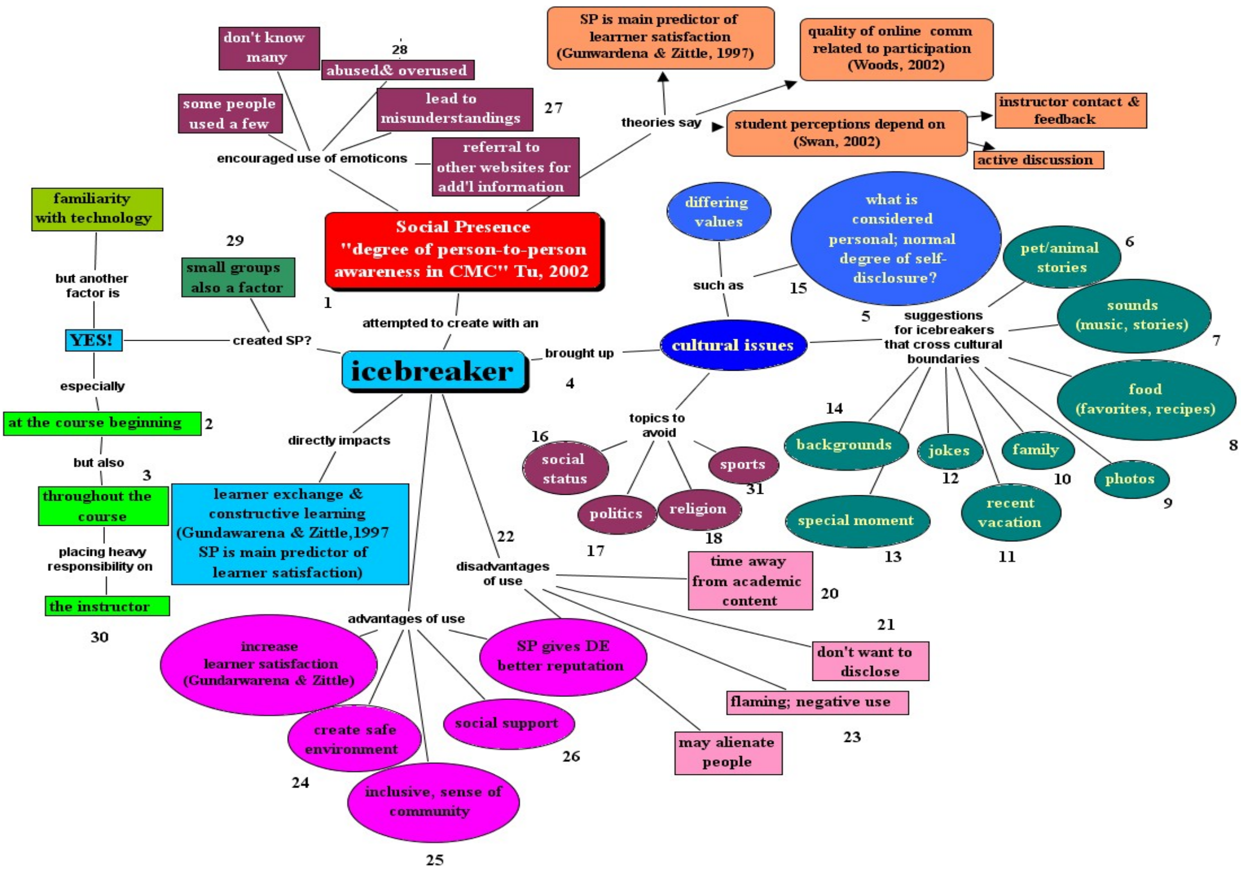

Figure 2. Concept map synthesizing social construction of knowledge in the Social Presence computer conference

4.2.1 Computer Conference: Learner Support

The four moderators divided the whole group into two subgroups with two moderators per subgroup. The moderators proposed a role playing scenario to solve learner support issues in a distance education context. The scenario was focused on creating an online disease prevention program for a rural community. They assigned a role to each participant, to wit: designers, administrators, instructors, and students. A total of 145 messages were generated. Group A generated 37 messages during the first week, while Group B generated 50 messages. During the second week all groups met together to respond to a common question in a common space. They generated 58 messages together. All discussions in Groups A and B ended the first week discussion with very detailed summaries (written and concept maps) that synthesized the main ideas proposed by each group. All groups agreed that these summaries helped them to go further in the activities proposed for the discussion in the second week.

During the second week both groups were back together in the same discussion environment to solve a common problem. The second week's discussion was characterized as moving toward phases III and IV. Conference participants also posted many new ideas, supported by the reading and instructional materials. By the end of the second week, the group was starting to summarize their agreements, moving toward phase V. The transcript analysis provided evidence that the groups socially constructed knowledge and approached the higher phases of the Gunawardena, et. al. model. The concept maps generated synthesized the social construction of knowledge that occurred in the group discussion. Overall, the learner support discussion indicated that the group was cohesive and created a sense of online community. This group's transcript analysis results and concept map are not presented in this paper because of space limitations.

4.3 Research Question 2

This question examined how moderators perceived the usefulness of concept maps for: synthesizing ideas; organizing the group contributions; communicating ideas; working in collaboration; and enhancing collaborative learning in a distance education context. After analyzing the responses provided by the students in the moderators' survey, it was observed that all groups perceived the usefulness of using concept maps for two main areas: 1) synthesizing and 2) organizing online computer conferences. All students agreed that the use of concept maps was an important information management tool, especially given the considerable amount of information generated (between 80 to 145 messages). It was also evident that the groups did not use CmapTools v3. software as a communication tool nor a collaboration tool in the online environment. Only the group that discussed social presence, showed one attempt to collaborate using the facilities of the CmapTools software, opening a discussion thread in the concept map created, although they recognized that they agreed about their ideas in previous face-to-face meetings. This group preference could suggest that they must be trained not only on how to use concept maps, but on how to communicate and collaborate using a concept map as a base.

This analysis served as a source of information to determine to what degree groups used CmapTools to communicate and to collaborate. However, it should be emphasized here that the use of Cmap to communicate and collaborate was not a mandatory task. Reasons given by the groups for not using the software in this way were first and foremost because of the complexity of using concept maps as a base for online group communication. They recognized that it was time consuming to try to interact using a concept map as the main communication tool, and also found that they were most comfortable interacting in face-to-face meetings. Another reason the groups gave for not using Cmap in this manner was the technology, which they argued necessitated their computer having specific hardware characteristics to support the use of the software. Students also felt overwhelmed with simultaneously learning content, dealing with technology, and working with concept maps all. It is argued that the generation of online communication based on concept maps is a complex process that takes time to develop and assimilate. All groups were asked for opinions about the use of web-based concept maps to enhance collaborative learning in distance education. Despite the difficulties cited above, a majority of the groups agreed Cmaps could be useful for enhancing collaborative learning (79%).

5 Conclusions

By comparing social construction of knowledge in text based dialogues to concept maps generated to synthesize this knowledge construction, this study showed that concept maps are an effective tool to synthesize knowledge construction in online conferences. This finding was also supported by self-reported data in a moderator survey. Concept maps were also considered an effective tool for organizing information which indicates that concept maps can be utilized as a knowledge management and preservation tool in online conferences. However, most of the students who participated in this study used concept maps to communicate ideas and collaborate among their small groups in the face-to-face situation, instead of in the online environment. Even though students did not explore the CmapTools facilities in the online environment, they acknowledged that Cmap would be a powerful tool to encourage and foster collaborative learning in online distance education courses. One main finding was that collaborative construction of a concept map could extend knowledge construction in computer conferences, as observed in the group that moderated and summarized the social presence computer conference. We observed that collaboration using concept maps requires individuals to integrate each other's ideas using a higher level of thinking. That process is complex, requiring skill and time which may not be readily available in a semester long course. While it is possible to use concept maps as a collaborative tool, it is important to provide training not only in the use of the software but also on how to collaborate using concept maps in an online environment. In this study, participants were able to generate, save, and post concept maps in the online discussion environment, but they used them as a collaborative communicative tool in face-to-face situation. It is recommended to replicate similar studies where face-to-face is not an option, to better understand the usefulness of the web-based concept maps in foster collaborative learning in online setting. We also found that students with low technology experience and no previous knowledge about concept maps can learn how to use the tool with a few hours of training and ongoing support during the semester. The future bodes well for continued investigation of the use of web-based concept mapping techniques to support many forms of online collaborative learning, especially when those techniques are used in a collaborative problem solving situation.

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EFFECTS OF SHORT TERM TRAINING IN CONCEPT-MAPPING ON THE DEVELOPMENT OF METACOGNITION

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Abstract: Considering the fact that academic curricula asks of students to perform better in an ever increasing information world and to be able to solve problems efficiently, this study was aimed at verifying if students will develop metacognition, the ability to reflect on one's own cognitive processes to a significant degree, after receiving a short term training in concept-mapping, an information organizing tool. The research was done with subjects in a 10th grade Physical Science course. Through the course of three types of tests such as a questionnaire on metacognition, predictive self-evaluation of exam results and "thinking aloud" problem solving sessions, it has been found that there were no significant differences between the subjects who had a short term training in concept-mapping without an explicite accent on metacognitive behavior and those who had not. Thus, in the context of this study, short therm training in concept-mapping has no apparent effect on the development of metacognition.

1 Introduction

As educational reforms engulf many countries, the priority is not concentrated as much on teaching but rather on learning. Notions and concepts belonging to a given domain come second. For Alvin Toffler, "the illiterate of the 21st century will not be the ones who do not know how to read and write but rather the ones that will not be able to learn, unlearn and relearn." These reforms place a lot of importance on the development of competencies which are linked to information treatment and problem solving. Actually, in general, today's academic curicula doesn't yet encourage "the conscious control" of learning. Study programs should incite students not to search to increase their academic performance but rather to improve their cognitive processes (Glaser and Pellegrino, 1987). It would therefore be essential to develop "how to think" processes, the consciousness and regulation of learning strategies called metacognition.

The infatuation for metacognition has pushed many to search for an efficient training method which would enable students to become more metacognitive. It is therefore a rather recent preoccupation and little research and pedagogical documentation have yet proposed as of today any reliable method which is easily adaptable to develop metacognitive abilities in the classroom. There has been research which describe the efficiency of certain approaches but, most of the time, these methods were specific to a given context and hardly transferable. It is our opinion that such training programs require either a heavy and long term training or are practically unapplicable in the classroom. In fact, training programs in metacognition suggested to this day often possess deficiencies at one or many levels such as: adaptability, transferability, applicability, reliability, and contextualization.

There doesn't seem to exist researches which have demonstrated that concept-mapping training has an effect on the development of metacognition. Also, teachers are confronted to important time constraints and an impressive quantity of concepts to cover during the school year. With this in mind, the inclusion of a short term training program in concept-mapping should avoid an increase in the teachers' workload. Before proposing such a training to teachers, it is preferable to find the answer to a pressing question: what are the effects of a short duration training in concept-mapping on the development of metacognition?

2 Concept Mapping

In education, concept-mapping holds its origins in Ausubel's (1963) work on meaningful learning. Other researchers, such as Lindsay and Norman (1980) and Collins and Quillian (1969) from cognitive psychology and information treatment, have also studied cognitive processes, modelization of memory and the representation of knowledge according to a theoretical approach of semantic networks. Later, Ausubel's theory has led Novak, Gowin and Johansen (1983) and Novak and Gowin (1984) to develop more specifically the strategy of concept-mapping.

Concept-mapping (conceptual or semantic networks) correspond mainly to the process of putting together a map with concepts. Concept-mapping in this research is based on the works of Novak and Gowin (1984) and as such is considered as a tool for the synthesis of information which facilitates the organization of knowledge. Some theorists, such as Lindsay and Norman (1980) and Collins and Quillian (1969), perceive these networks as representations of what is stored in memory. Seen in this light, Novak's concept-maps would be the tool itself, an educational adaptation of the semantic networks of Collins and Quillian.

Metaphorically, Wandersee (1990) views concept-mapping as a road map. As in such a map, a concept-map would contain elements enabling us to find our way or to go from one point to another. In concept-mapping, the territory to explore would be the memory and its cognitive structure. The destinations and the cities would become the concepts. Then, the roads to get there would be the links between the concepts. The links reach all the destinations. They render explicite knowledge that is relatively implicite or organized (Patry, 2003). We can simply say that concept-mapping is the process through which a concept-map (the end result) is assembled.

There are many components in a concept-map that render it relatively rich and precise. Concept-maps developed by Novak and Gowin (1984) should contain the following components: concepts, links, link propositions, crosslinks and exemples.

In our view, the process of building a concept-map starts with the person who makes the map, from his life, experience, his knowledge, his motivation, etc.. The building is "holistic" in the way that its forces the individual to touch his overall knowledge and experience on a given subject. Through an iterative process, the concept-mapper searchs first the concepts important to the subject studied. Afterward, he categorizes them in groups and sub-groups. Then he puts them in hierarchies from the most general concept to the most inclusive one. Finally, he establishes relationships with links, link propositions and crosslinks and examples if need be. To make sure of the "solidity" of his concept-map, it is recommended that the concept-mapper has it evaluated by another person. In this way he vould receive valuable feedback on his creation.

3 Metacognition

In 1976, Flavell defined metacognition as such:

"Metacognition refers to the knowledge one has of his own cognitive processes and their products (...) it touches, among other things, the active control, the regulation, and the orchestration of these processes (...) so as to serve an objective or a concrete goal." (p 232)

According to Flavell (1987), metacognition can appear during many situations: 1) when the situation requires it explicitely; 2) when the cognitive situation is at once new and non-familiar; 3) during situations when it is necessary to make inferences, to use critical thinking, and during decision making; 4) when the individual has difficulties during problem solving.

Even though many nuances have been given surrounding the concept of metacognition, most researchers agree to the fact that metacognition contains two main components: metacognitive knowledge which an individual possesses and his self-regulation mecanisms (figure 1).

Metacognitive knowledge refers to the "what" of our cognitions. This knowledge is the set of knowledge that a leraner possesses on his own cognitive ressources and which could serve him to direct and organize himself during a learning or problem solving situation.

Flavell (1976, 1987) considers three different variables linked to metacognitive knowledge: the knowledge related to the individual, the knowledge related to the task, and the knowledge related to strategy. These three variables are in constant interaction. The variable "individual" refers to the knowledge and beliefs carried by the learner on himself; for example: "I know that I am able to...". The variable "task" covers the information and the constraints within a given problem and which the learner is aware; for example: "I know that task X is easy." The variable "strategy" is linked to the strategies which the learner possesses consciously and that will enable him to be efficient during problem solving; for example: "I know which strategy to use and which one is useless."

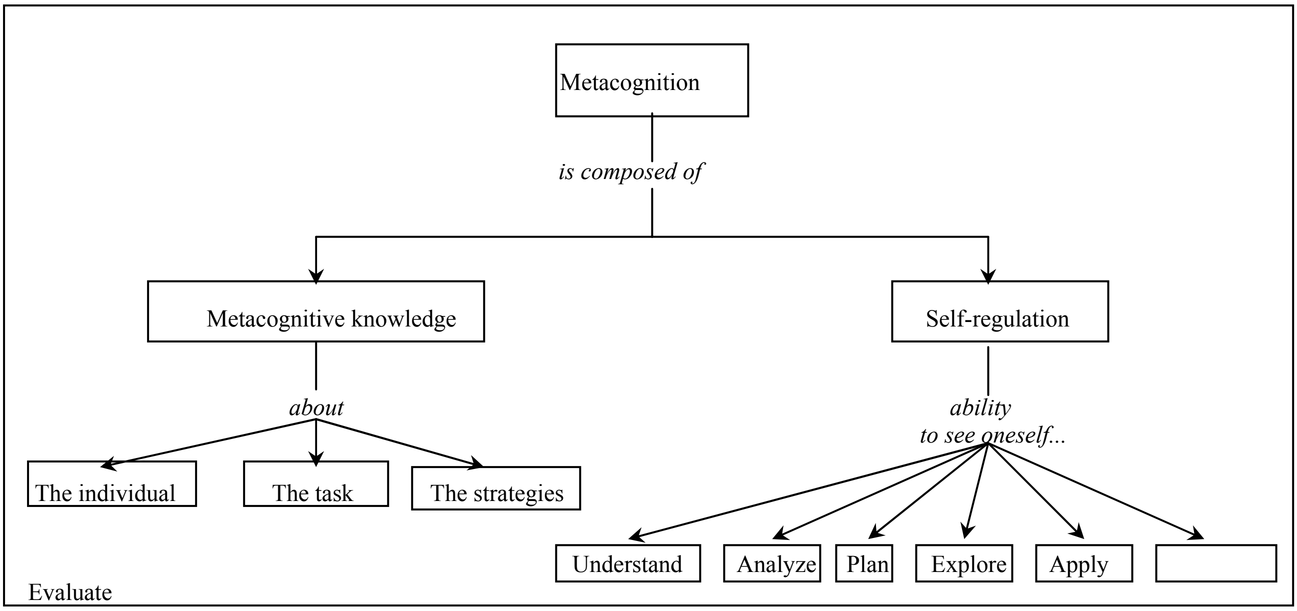

Figure 1**. Components of metacognition**

The other component of metacognition, self-regulation, is a complex concept whose definition is constantly evolving. Many authors such as Allaire, Pallascio, Lafortune, and Mongeau (1998) consider self-regulation as a set of metacognition abilities for it refers to the control of the "how to" of our cognitive processes.

Self-regulation would therefore be a conscious process which consists of the use of metacognitive abilities and strategies so as to execute a given task. According to Artzt and Armour-Thomas (1990), inspired by the works of Garofalo and Lester (1985) and Schoenfeld (1983), there are six such metacognitive abilities: understanding the problem, analyzing the problem, planning the stages of the task, exploring, applying, and self-evaluation (figure 1). An ability is said to be metacognitive when the learner sees himself executing a given cognitive process (ex.: to see oneself understanding the problem). The learner talks to himself outloud or in thought. The learner thinks about his thoughts (Pallascio, Benny, and Patry, 2002; Fisher, 1998). Table 1 presents a short description of each metacognitive abilities.

Metacognitive abilities (so see oneself...)	**Description**
... understand the problem	Examination of knowledge related to the task
...analyze	Breakdown of the problem in its basic elements and reformulation of the problem
...plan the task	Selection of the steps to solve the problem
...explore	Regulation of one's progress and action
...apply the steps	Decision making
...evaluate (self-evaluation)	Return on decisions and actions

Table 1: Description of metacognitive abilities.

Self-evaluation is considered as indicative of the learner's overall degree of metacognition. Mariné and Huet (1998), among others, go further by subdividing self-evaluation into prospective and retrospective. Prospective self-evalaution is the feeling *a priori* regarding one's own future performance in a given task. Retrospective sel-evaluation is the feeling *a posteriori* of one's own performance after the task.

From the information gathered above, we can ask some questions. Can we develop students' metacognition since it renders them more autonomous and improves their academic performance? Do training programs exist which are quick, efficient, adapted to different learning levels, and applicable in classe?

Presently, there exists a certain consensus in education that it would be important to develop an awareness and the regulation of thoses learning strategies which are called metacognition since the research from Flavell. Thus, when metacognitive abilities are developed in a learner, his academic performance improves (Landine & Stewart, 1998). A metacognitive learner is more mature, more autonomous concerning the control of his own learning and behavior during problem solving (Brown, 1987).

Teaching of metacognitive strategies should facilitate attention span, motivation, learning, the memory, and understanding as well as help in solving certain learning problems (Wittrock, 1986). By its heuristic and educational nature, metacognition appears therefore, for many, as an essential component of learning. Some researchers, such as Noël, Romainville, and Wolf (1995) even propose that schools become centers for the development of metacognition where students are trained to become aware of their learning processes and master those acquisitions.

Nevertheless, there exists a controversy regarding the advantages of metacognition. Indeed, according to a meta-analysis by Romainville (2000), it seems that certain training programmes to develop metacognition have not been as efficient as predicted compared with their goals, such as improving metacognition and academic performance.

Earlier in the text we have seen that concept-mapping is a tool to synthesize and organize information. Would a student, trained in concept-mapping through a short program, develop his metacognition? The answer to this question could permit us among other things to ensure that such a technique, concept-mapping, is worthwhile to develop metacognition thus saving time and energies.

4 Methodology

The present study has been done with 10th grade Physical Science students from urban Montréal (Patry, 2003). Two groups from regular physical science classes have been randomly assigned to the teacher. The students had been assigned to each group randomly by the school's computer. Then, again randomly, one group was designated experimental while the other became the control group. However, within each of these groups, we have retained only those students who were up to date in math and French and hadn't done this science course previously. At first, the experimental group had 20 subjects, the control group, 21 subjects. During the process of testing, some subjects were removed from part of the study for different reasons such as absence or not answering some questions. However, for practical reasons, within these two groups we selected a small sample (exp. = 6, ctrl. = 8) for the "thinking aloud" tests on proportion reasonning tasks (Côté & Noelting, 1971).

Concept-mapping training was applied only to the experimental group. Since the content of the Physical Science course is very heavy, we have chosen a short duration training program (Patry, 1998). In this previous study, after such a training, there had been a significant difference between experimental, semi-experimental and control groups in concept-mapping capabilities. Indeed, in a physical science context the experimental and semi-experimental groups were equally better concept-mappers than the control group. However, when all groups had to transfer these competencies to another domain (history), the experimental group was significantly much better than the other two groups.

At first, the subjects went through a class of 75 minutes during which they were explained everything about a concept-map, its design and construction and they did exercices. This introduction was followed by 5 sessions of 45 minutes spread throughout four months of practical classes with the construction of concept-maps and the use of progressive devolution concept-maps at the end of every segments (x4). These maps are concept-maps in which a growing proportion of concept is removed with each passing segment. Two months after the end of the treatment, both groups were administered the post-tests described below.

Apart from the introduction above, the students performed the sessions with the same teacher who had received a similar but more advanced training. The Physical Science course as taught in the province of Québec is a mixture of traditionnal and participative approach. Students are encouraged to develop their critical thinking through the practice of the scientific method and performing lab experiments. Little is done to develop at this point "metacognitive behaviors". During training, students were motivated to complete their maps for it was explained to them that in doing so it would enable them to identify erroneous conceptions and synthesize at the end of a given segment the information they received in the previous classes.

5 Results

The independant variable corresponded to the short term training program in concept-mapping. The dependant variable, metacognition, was subdivided in three sub-variables to which was associated a different measuring tool for each one. Metacognitive knowledge was evaluated with the help of a questionnaire called COMÉGAN on metacognition (Richer, Mongeau, Lafortune, Deaudelin, Doudin & Martin, 2004). In this test, the subjects chose a level on a Likert scale (disagree, agree, etc.) for 18 statements during a problem solving situation such as: "I know the strategies which help me the most to learn", I can name my strong points which help me to learn better", "I know what type of tasks are easy for me." Self-regulation was analysed with "thinking aloud" tests on proportion reasonning task so as to mesure the frequency in the use of metacognitive abilities. And last, self-evaluation (prospective and retrospective) has been evaluated from knowledge exams in mathematics and science. Self-evaluation is often used as a global indicator to determine the degree to which a learner is metacognitive (Huet, Mariné & Escribe, 1994; Osborne, 1998, 1999; Wilson, 1997).

During pre-testing, we have found that the two groups were equivalent for every measuring tool. Afterwards, to compare the two groups, we have mainly used "t" tests for mean comparison. This choice has been motivated by the fact that the number of subjects was small and the selection process was not completely random (see above).

Concerning metacognitive knowledge (table 2), we have found that at the post-test, there were no significant differences between the two groups (t = 1,27, p > 0,10).

		Pre-test			Post-test		
Groupes	N	M	s	t	M	s	t
Experimental	18*	51,81	5,92		52,92	6,27	
Control	14*	55,00	6,21	0,149 (n.s.)	56.11	4,87	0,127(n.s.)

n.s. : non significant (p > 0,05)
* The difference in sample sizefrom its original number is due to the f act that some subjects were absent.

Table 2: Metacognitive knowledge (test « t », independant sample).

So as to analyse the frequency in the use of metacognitive abilities, we have proceeded to a statistical analysis with a Chi square test, X^2 for all of the statements since we had nominal data (table 3). Analysis demonstrated that there were no significant differences between the two groups at the post-test ($X^2 = 0,103$, df = 1, p > 0,70).

	Pre-test		Post-test	
Statements	Contr. N = 8	Exp. N = 6	Contr. N = 8	Exp. N = 6
Metacognitive	104 (58%)	125 (58%)	56 (48%)	104 (49%)
Non-métacognitve	74 (42%)	92 (42%)	61 (52%)	109 (51%)
Sum Meta. + non- meta.	178 (100%)	217 (100%)	117 (100%)	213 (100%)

Table 3: Frequency in the use of metacognitive statements.

Regarding self-evaluation (prospective and retrospective), we compared the two groups in regards to the precision with which a subject predicted his performance before and after a test. For the prospective self-evaluation, each subject had to give a value which indicated the success level for a given problem (from 0 = failure to 4 = success) **before** solving the problem. For retrospective self-evaluation, the subject had to proceed likewise, this time **after** solving the problem. We have calculated the differences between the value given by the subject (prospective and retrospective self-evaluation) and the actual performance (maximum of 4 points). These differences gave us the degree of disagreement between these values (tables 4 and 5).

	Pre-test				Post-test			
Groups	N	M	S	t	N	M	s	t
Experimental	20	8.85	2.72		19*	7.26	3.33	
Control	21	7.81	2.73	1,22(n.s.)	21	6.80	2.31	0.51(n.s.)

n.s. = non significant (p > 0,05)

Table 4: Prospective self-evaluation. Means of the sum total of the degrees of disagreement.

	Pre-test				Post-test			
Groups	N	M	S	t	N	M	s	t
Experimental	20	6.50	2.31		18*	7.44	3.29	
Control	21	6.57	3.36	0.08(n.s.)	16*	7.06	2.14	0.40(n.s.)

n.s. = non significant (p > 0,05)

* The differences in the number of subjects are due to the fact that some of them have not answered some questions in the self-evaluations.

Table 5: Retrospective self-evaluation. Mean of the sum total of the degrees of disagreement.

For the prospective self-evaluation, we have observed that there were no significant differences between the two groups during the post-test (t = 0,51, p > 0,60). Regarding retrospective self-evaluation, there again, there were no significant differences between the two groups during the post-test (t = 0,40, p > 0,60).

Our analysis has demonstrated that a short term training program in concept-mapping as used in this study has no effect whatsoever on the development of metacognition. Concept-mapping encourages mainly the organization of information and structures this organization without necessarily implying self-questionning typical to the metacognitive process. The learner organizes himself better without necessarily self-regulating.

We may ask ourselves if the training itself, its short duration was appropriate. On the other hand, the heavy content of present curricula doesn't allow us for the moment to give more time. Metacognition remains difficult to measure quantitatively. We used tests that aimed at measuring specific components of metacognition. Maybe, for students having attained the formal stage, the reasoning test has been easier to solve and corresponded more to a situation during which one applied a rule. Consequently, it was not conducive to the expression of a metacognitive reasoning. The test could have been more adapted for students about to attain the formal stage. Nonetheless, even though our sample was small, we perform three different tests and the results of our stastical analysis point out that a short term training in concept-mapping doesn't affect the development of metacognition.

6 Summary

The desire to encourage the learner to become aware and master his own regulation processes during a problem solving situation is essential. In this study, we wanted to know if it was possible to develop such competencies, metacognition, to accelerate its evolution through a rapid training in concept-mapping. During this training, we tried to avoid any references to metacognition so that we could really study a basic program on concept-maps training. However, the results of our research do not demonstrate that a short duration in concept-map training affects the learner in this sens. Metacognition, the awareness and control of our own cognitive processes, is in fact a "work in progress". It develops throughout the years as the learner matures. Concept-mapping helps him to learn how to learn, to organize and synthesize his knowledge. For many decades, a lot of emphasis has been put on content (notions, knowledge) by the teaching community. Less on the "how to learn" approach. The present study shows that there is no "quick fix". The learner, the brain, must take time and practice to develop his competencies. We may ask if a longer training period linked directly to problem solving with an approach explicitely metacognitive could produce better results. It is, according to us, in this direction that research aiming to identify an efficient stratetegy to develop metacognition should go. There remains a lot to learn about metacognition and programs which encourages its development. It is motivating to know that there is still more territory to explore.

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MAPAS CONCEPTUALES: ELEMENTOS FUNDAMENTALES PARA LA INTERVENCION

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Resúmen. Se trata de una investigación que proporciona importantes instrumentos de trabajo para el aula, en el área de matemáticas, principalmente para el logro de aprendizajes significativos en el sentido ausubeliano y en concordancia con los principios constructivistas actuales. El artículo versa sobre el papel fundamental que juegan los mapas conceptuales en el Programa de Intervención llamado SAM (Sistema de aprendizaje mediado). El Programa SAM armoniza las ideas fundamentales en torno a la construcción del conocimiento expuestas por Ausubel y Novak, sin olvidar algunos elementos en común que éstas tienen con las aportaciones de Piaget y Bruner, para lograr el desarrollo de capacidades cognitivas. El profesor del Programa, apoyado en mapas conceptuales y actuando como mediador entre el contenido y el alumno, contribuye para que el aprendiz logre un aprendizaje constructivo, significativo y por descubrimiento. El Programa SAM fue diseñado en México para el aprendizaje del cálculo en el nivel universitario. Junto con los mapas conceptuales elaborados por el profesor y por el alumno, el Programa tiene por objetivos el desarrollar el razonamiento lógico y la orientación espacial. Como producto de la utilización de mapas conceptuales a través de la aplicación del Programa SAM se ha apreciado un aumento significativo en el cociente intelectual de los estudiantes y también un mejor rendimiento académico en el proceso de aprendizaje en las aulas universitarias.

1 Introducción

Por el valor educativo de las matemáticas, ya que es un contenido (como muchos otros) a través del cuál se logra el desarrollo de la cognición en el estudiante, su aprendizaje es un tema que ha venido siendo estudiado con profundidad por los expertos del ámbito escolar. Las matemáticas han llegado a ser consideradas, incluso, como una asignatura muy importante para la educación en todos los niveles, desde la educación primaria (educación básica) hasta los niveles universitarios. En el ámbito de la ingeniería así como en otras disciplinas, el conocimiento de las matemáticas, además de permitir el desarrollo cognitivo –desarrollo de capacidades como el razonamiento lógico o la orientación espacio-tiempo–, constituye un pilar fundamental para el aprendizaje de las ciencias aplicadas.

A pesar del reconocimiento de la importancia de las matemáticas, dirigiendo la vista a las instituciones educativas, tanto de niveles básicos como de niveles universitarios, se aprecian y se distinguen situaciones difíciles. Es importante decir que, a pesar del gran potencial educativo que tienen las matemáticas –una gran oportunidad para desarrollar la cognición–, 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 generado un aumento en el interés por emprender, desde diferentes posturas, estudios que den una alternativa o guía para la enseñanza y el aprendizaje de este contenido.

Con el propósito de aportar información que contribuya en alguna medida en los aspectos relacionados con la enseñanza y el aprendizaje de las matemáticas, surge la iniciativa de emprender una investigación concretada en un Programa de Intervención llamado SAM (Sistema de aprendizaje mediado). Se trata de un Programa de Intervención –una manera especial de actuación en el aula– que considera el contenido matemático como el vehículo para desarrollar la cognición en el estudiante, entendiendo el desarrollo cognitivo como el desarrollo de un conjunto de destrezas que, a su vez, conforman un conjunto de capacidades cognitivas (Román y Díez, 2000). Es un Programa de Intervención cuyos fundamentos teóricos son característicos del paradigma cognitivo en educación y uno de sus elementos fundamentales son los mapas conceptuales.

2 Programa SAM

El Programa SAM permite el desarrollo de un conjunto de capacidades y destrezas (dimensión cognitiva) por medio de la socialización contextualizada (dimensión sociocultural). Siguiendo estas ideas, el Programa se ubica tanto en el paradigma educativo sociocultural como en el paradigma cognitivo. El SAM tiene cabida en "un paradigma integrador socio cognitivo" definido por Román y Díez (1998).

El Programa toma en consideración los procesos de pensamiento tanto del profesor como del alumno, así como el entorno y la vida en el aula. Se trata de un Programa que sigue el modelo Aprendizaje-Enseñanza (cómo aprende el que aprende para, en función de ello, diseñar la enseñanza) y sirve como una herramienta para lograr el aprendizaje escolar en donde el profesor actúa como mediador del aprendizaje.

El SAM, a través de los mapas conceptuales, permite dar significación y sentido a los conceptos y hechos, es decir, permite el aprendizaje significativo y constructivo. Permite también la estructuración de manera significativa de la experiencia y la facilitación del aprendizaje compartido. Esto, a su vez, potencia el interés y la motivación, y facilita el desarrollo de capacidades y destrezas.

Con la utilización y construcción de mapas conceptuales, el SAM permite un aprendizaje de los contenidos de manera constructiva y significativa, y además un adecuado almacenamiento de éstos en la memoria para disponer de ellos cuando se requiere. Es muy importante señalar que con un aprendizaje de calidad se facilita la utilización de los contenidos en la vida cotidiana.

El programa considera, por una parte, a las capacidades y destrezas cognitivas como objetivos y, por otra parte, el contenido matemático y los métodos (acciones en el aula) son considerados como medios para conseguir los objetivos. Desde este punto de vista, el Programa orienta la enseñanza hacia el desarrollo cognitivo y es por esto por lo que se considera un Programa de Intervención cognitiva. El SAM pretende incorporar al alumno como protagonista de su aprendizaje para que de sentido a lo que aprende y sentido al escenario en donde aprende. El profesor del programa actúa como mediador averiguando cómo aprende el que aprende y qué sentido tiene lo que aprende.

2.1 El diseño del SAM: aspectos generales

Como modelo de aprendizaje-enseñanza, el Programa de Intervención fue diseñado con un enfoque sistémico, como se muestra en Figura 1. Es un Programa que consta de tres elementos relacionados entre sí: el elemento Aprendizaje, el elemento Profesor Mediador y el elemento Arquitectura del Conocimiento en donde reside una de las partes fundamentales del Programa: los mapas conceptuales.

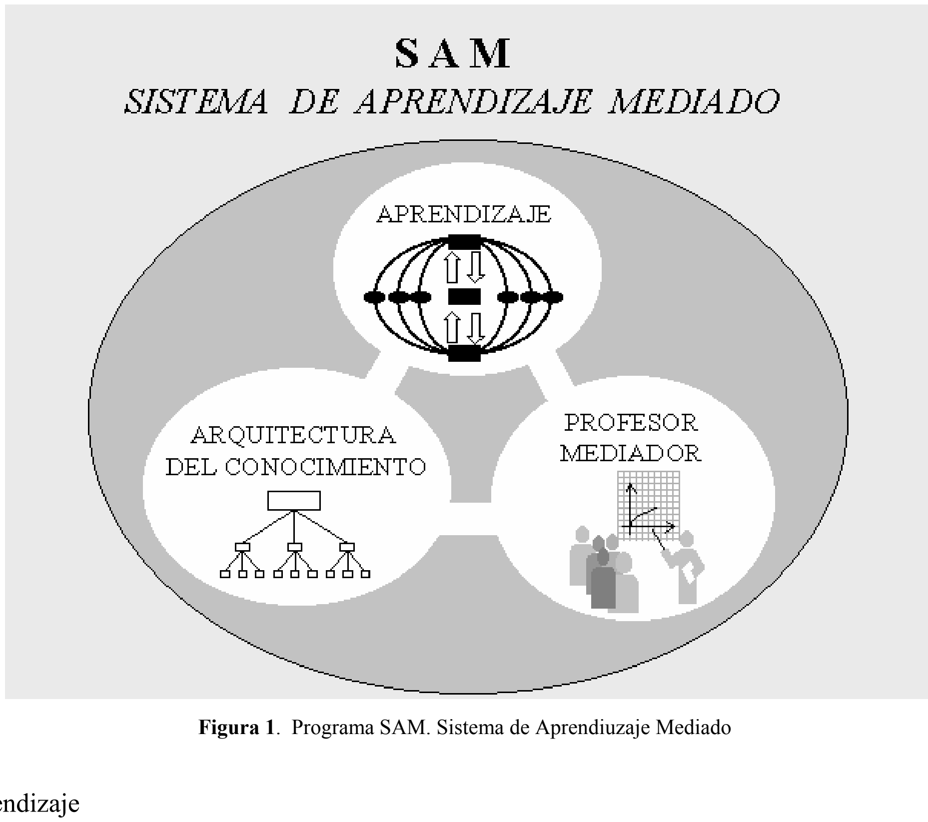


Figura 1. Programa SAM. Sistema de Aprendiuzaje Mediado

2.1.1 Aprendizaje

El aprendizaje Constructivo, el Significativo y el aprendizaje por Descubrimiento —con tres etapas básicas de aprendizaje en común: la percepción, la representación y la conceptualización— son el fundamento que sugiere al mediador una forma de actuación en el aula. Estos tres enfoques del aprendizaje informan al profesor sobre la forma en que el alumno aprende.

El aprendizaje Significativo descrito por Ausubel es el fundamento de los Mapas Conceptuales del Programa SAM. Han sido incorporadas al Programa en una forma armónica algunas ideas en torno al aprendizaje constructivo y por descubrimiento, aportaciones de Piaget y Bruner respectivamente. Con esta armonización se ha obtenido una pauta para manejar el contenido adecuadamente sabiendo como aprende el que aprende.

2.1.2 Arquitectura del Conocimiento: Mapas Conceptuales

El Modelo Didáctico Arquitectura del Conocimiento es el material de apoyo para el mediador: se trata del conjunto de mapas conceptuales. El Modelo es una forma de arreglar y disponer el contenido de tal forma que, desde lo más particular (hechos, ejemplos y experiencias) hasta lo más general (conceptos, leyes, teoremas, principios...) respeta los niveles básicos del aprendizaje, permitiendo un aprendizaje constructivo, significativo y por descubrimiento; desde luego, tomando en consideración la actuación del profesor como mediador.

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. Tal como lo explica Ausubel, los procesos de pensamiento inductivos y deductivos son potenciados al disponer la información respetando las jerarquías conceptuales, logrando aprendizajes subordinados y supraordenados, partiendo desde lo particular hasta lo general y viceversa. Finalmente, desde la óptica de Bruner, partir desde un sistema enactivo hasta un sistema simbólico, permite el desarrollo de procesos inductivos. Todos estos aspectos son considerados por el profesor mediador del Programa SAM para la construcción de mapas conceptuales. Estos (Novak, 1998), desempeñan en el aula una función clave para representar los conocimientos. Es importante señalar que 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).

2.1.3 El profesor mediador

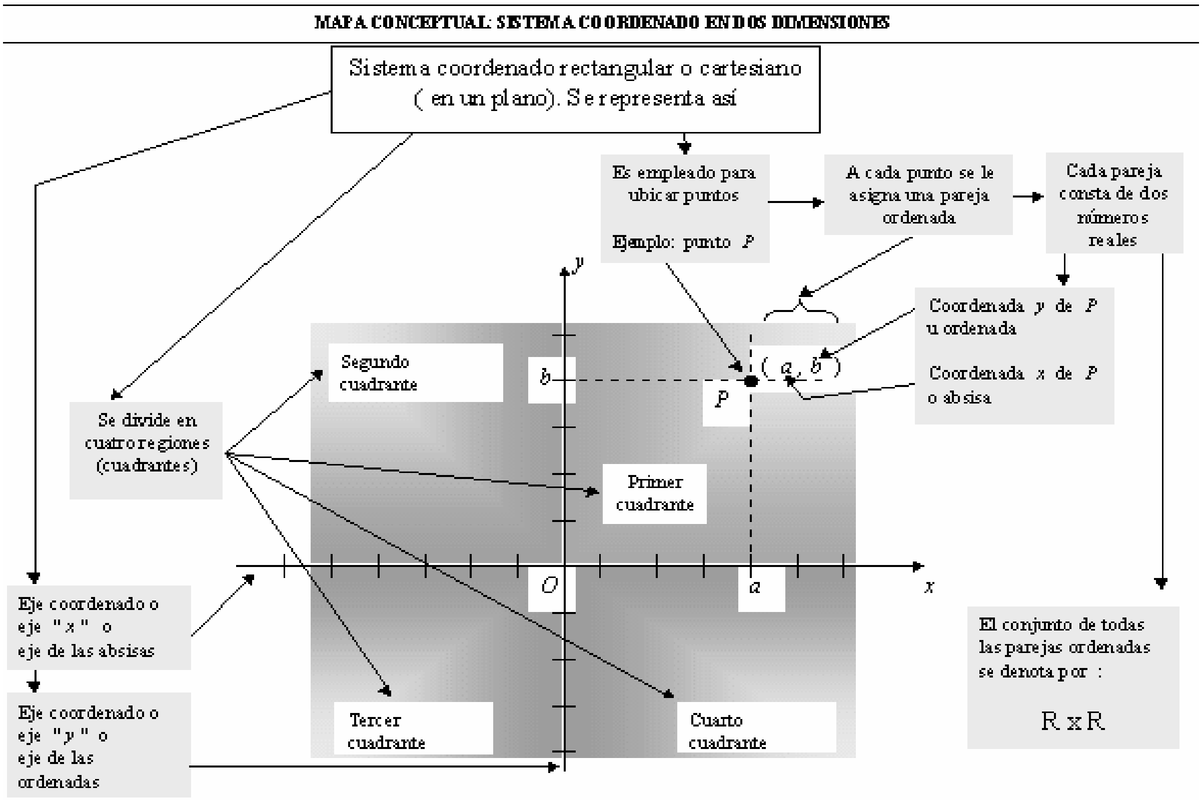
El profesor como mediador en el Programa SAM planea su actuación, es decir, su enseñanza en el aula, teniendo en consideración la manera en que el aprendiz aprende, desde el punto de vista del aprendizaje Significativo, Constructivo y por Descubrimiento. Se trata del profesor en cuyas características y actuación se toma en consideración la zona de desarrollo próximo. El mediador en el Programa se apoya con la elaboración del Modelo Arquitectura del Conocimiento: con la elaboración de los mapas conceptuales.

2.2 Objetivos del Programa

El Programa SAM formado por tres elementos que interactúan entre si tiene como objetivo general: mejorar la estructura de la inteligencia, entendida como mejora de la ejecución intelectual, constatando dicha mejora en el C.I. obtenido con los instrumentos pertinentes.

El Programa tiene como objetivos por destrezas: 1. Desarrollar las destrezas de Inducción y Deducción consideradas como parte de la capacidad Razonamiento Lógico. 2. Desarrollar las destrezas Situar, Localizar y Expresar Gráficamente, consideradas como parte de la capacidad Orientación Espacial

Las figuras 2 y 3 en las siguientes páginas muestran algunos ejemplos de mapas conceptuales construidos para el Programa.



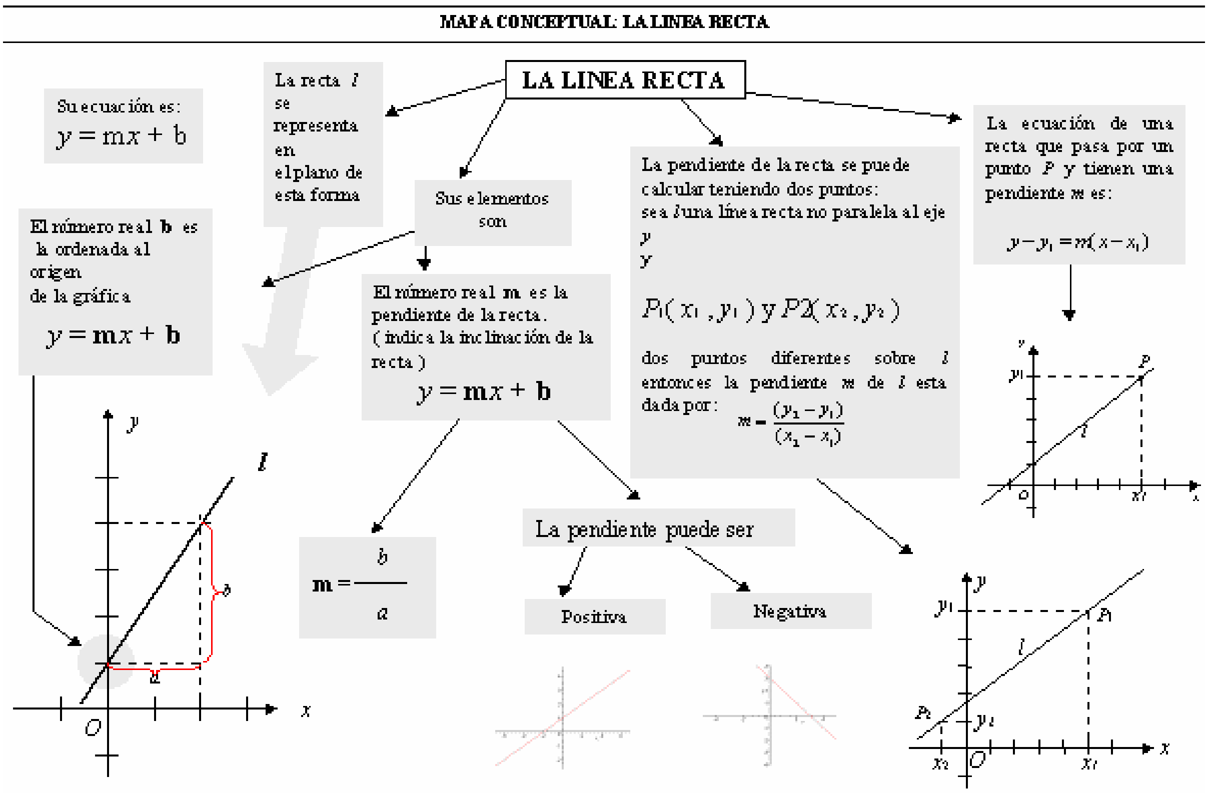


Figura 2. Ejemplos de mapas conceptuales del Programa SAM

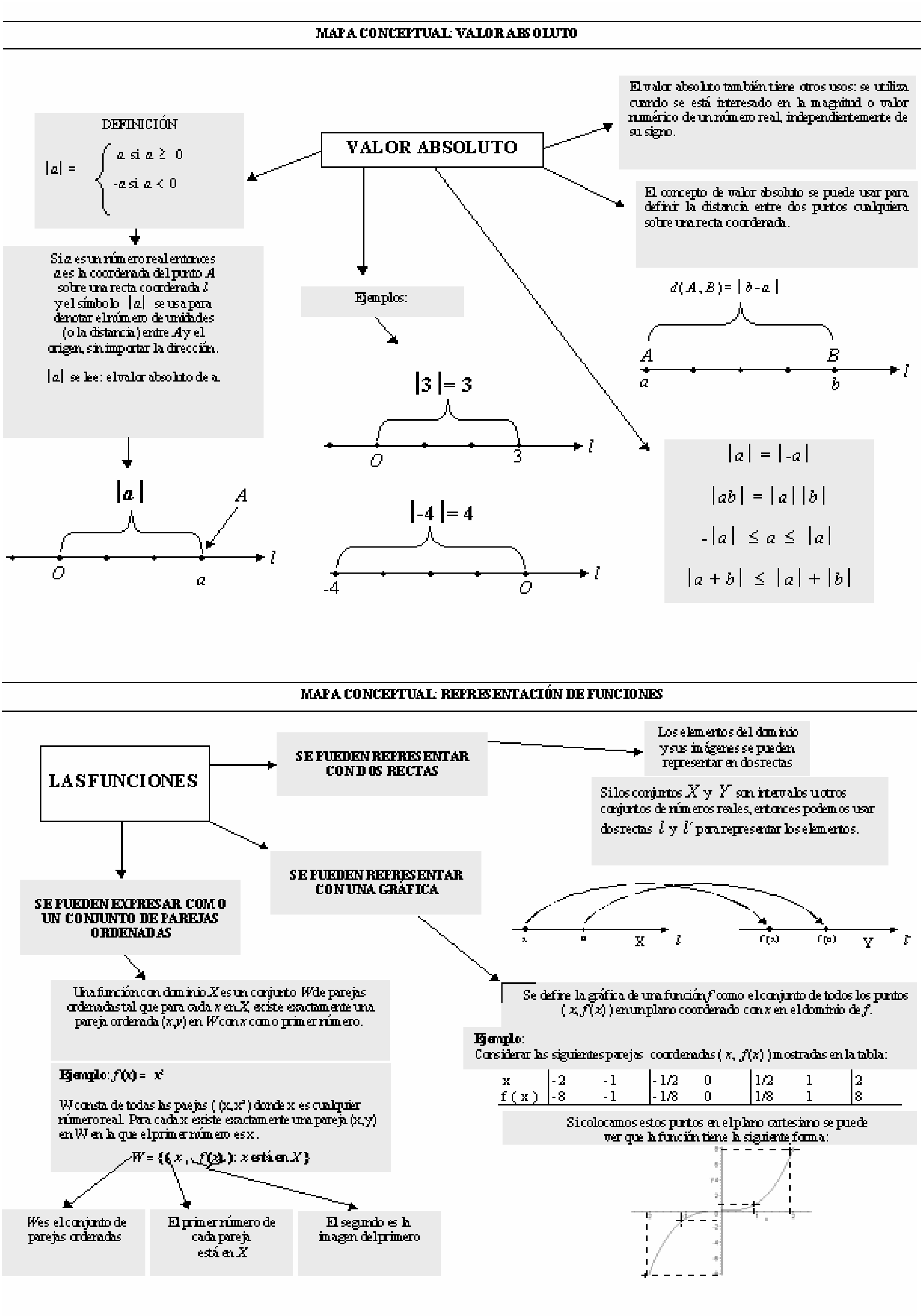


Figura 3. Ejemplos de mapas conceptuales del Programa SAM

2.3 Metodología Investigadora

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) y la fase post-test (puntuaciones una vez que finalizó el entrenamiento).

Se seleccionó un grupo de estudiantes al cuál se les aplicó las pruebas pre-test (Test Cattell y Raven) que miden la Inteligencia General (C.I.). 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 unos 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 experimental y control fueron homogéneos: no existió entre ellos diferencias estadísticamente significativas en el momento "pre" en cuanto a la Inteligencia General (C.I.). El grupo control inició con un curso ordinario de la asignatura "Cálculo I" y el grupo experimental con un curso de la misma asignatura pero con el Programa SAM.

El Programa de Intervención fue diseñado para ser aplicado tomando en consideración las características de la programación de la Universidad Autónoma Metropolitana (UAM). El Programa tuvo una duración de tres meses durante los cuales se tuvieron un determinado número de sesiones con carácter obligatorio. Además, el Programa 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 la aplicación del Programa (entrenamiento) se aplicaron las pruebas post-test a todos los estudiantes, tanto del grupo experimental como del grupo control.

Posteriormente se llevó a cabo un análisis de los datos obtenidos. A éstos se aplicaron las siguentes pruebas: Student´s **t** (Prueba paramétrica) y Rangos Signados de Wilcoxon (Prueba no paramétrica). Este análisis tuvo la intención de valorar las diferencias en los resultados obtenidos entre la fase pre-test y la fase post-test, entre los grupos experimental y control. 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"* aplicando el *"Programa de Intervención SAM"* 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 pero sin aplicar el *"Programa de Intervención SAM"* :

1. se observará un aumento significativamente superior de los C.I.s (Inteligencia General) —medido con el test "*Matrices Progresivas de Raven"*— en los sujetos del grupo experimental con respecto a los del grupo control.
2. se observará, también, un aumento significativamente superior de los C.I.s (Inteligencia General) —medido con el Test de Factor "g"— en los sujetos del grupo experimental con respecto a los del grupo control.

2.4 Resultados

Teniendo una identificación con los instrumentos que justifican la complementariedad metodológica de los paradigmas cualitativos y cuantitativos en la investigación educativa, en esta investigación fueron utilizados instrumentos tanto cuantitativos como cualitativos para llevar a cabo una evaluación de la aplicación del Programa SAM. Los instrumentos que se emplearon para realizar el registro cualitativo fueron: un diario de cada uno de los alumnos, un diario del mediador y las evaluaciones parciales. La información que plasmaron los estudiantes en estas evaluaciones informaron sobre los 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. Un análisis de toda la información plasmada en estos instrumentos permitieron concluir que:

- Los alumnos expresan el énfasis que el Programa SAM ha hecho sobre las etapas básicas del aprendizaje implícitas en los mapas conceptuales y sobre las actividades encaminadas a desarrollar destrezas. Consideran que los mapas conceptuales y las actividades (estrategias de aprendizaje en el aula) ayudaron a su aprendizaje.

- Los alumnos reconocen la importancia de la percepción y la imaginación (representación) para el inicio del proceso inductivo. Aprecian la importancia de los procesos inductivos para el aprendizaje de las matemáticas y la importancia de los mapas conceptuales potenciadores de la inducción, la deducción y la representación.
- Los estudiantes hablan sobre uno de los elementos fundamentales del Programa: hacen referencia a que han comprendido la teoría y no la han memorizado. Esto gracias a la construcción de mapas.
- Los alumnos han percibido la conducta del profesor mediador como favorecedora del aprendizaje.
- Los comentarios favorables que los alumnos expresaron se ven reflejados en los resultados de las evaluaciones parciales. Al final del Programa SAM, el 80% de estudiantes aprobó el curso.

Para llevar a cabo el registro cuantitativo se utilizaron los siguientes instrumentos: Test de matrices progresivas de Raven y Test de factor “g” de Cattell. Los resultados obtenidos permitieron verificar las hipótesis de la investigación. Habiendo procesado la información del Test de Raven para el grupo control y experimental con los modelos estadísticos, se observaron diferencias estadísticamente significativas sólo en el grupo experimental para un nivel de confianza del 99% entre PRE y POST. Se afirma que existió evolución significativa del C.I. en el grupo Experimental. Este aumento se explica principalmente por el efecto del Programa de Intervención aplicado a este grupo. De la misma manera, el procesamiento de la información del Test de factor “g” de Cattell reveló diferencias estadísticamente significativas para un nivel de confianza del 99% entre PRE y POST. Se afirma que existió evolución significativa del C.I. en el grupo Experimental. Este aumento se explica, también, principalmente por el efecto del Programa SAM aplicado a este grupo.

3 Conclusiones

Para el Programa de Intervención SAM, el aprendizaje de las matemáticas es entendido como un desarrollo de capacidades y destrezas. En este sentido, con la información estadística obtenida se puede concluir que el Programa permiteun aumento significativo de la inteligencia (entendida como mejora de la ejecución intelectual) en los estudiantes. Por otra parte, las aportaciones de los estudiantes, en los diferentes instrumentos, en torno a lo que han aprendido, proporciona una evidencia de ese desarrollo.

El profesor, procurando la interacción de los elementos que conforman el Programa SAM y actuando como profesor mediador, genera en el aula una atmósfera que propicia las actividades mentales en los estudiantes. 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: al desarrollar la inteligencia. 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 al uso de mapas conceptuales, 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 elemento Arquitectura del Conocimiento del Programa SAM, conformado por mapas conceptuales, al ser un apoyo para el profesor en cuanto a la manera de acomodar los contenidos, contribuye a la práctica de los procesos inductivos y deductivos. Contribuye para que el alumno contraponga conceptos con hechos y hechos con conceptos, para que el alumno parta de información particular percibida hasta la elaboración de generalidades y para que el alumno, a través de su actividad en el aula, descubra por sí mismo. Los mapas conceptuales en los que se apoya el profesor del Programa SAM contribuyen a la practica de pensamiento desarrollando así la inteligencia.

Sintetizando: el Programa de Intervención aplicado a la asignatura de "Cálculo I" desarrolla capacidades y destrezas tal como se ha visto en la aplicación de los test. Se entiende que el Programa SAM mejora el aprendizaje de contenidos.

Por último, como propuestas para el futuro, el terreno universitario necesita de nuevas investigaciones que contemplen los procesos de aprendizaje y enseñanza. Investigaciones que conjuguen, entre otros, elementos técnicos (contenidos) y humanos (aprendices y docentes) que contribuyan al enriquecimiento del conocimiento pedagógico en la universidad. La continua investigación en el terreno educativo universitario, con un aumento de muestras, permitirá llegar a niveles más altos de generalización mejorando, con ello, los procesos de aprendizaje y enseñanza.

La visión optimista de modelos de aprendizaje que contemplen estos tres elementos: Aprendizaje, Mediador y Arquitectura del Conocimiento: mapas conceptuales, despierta el interés y la necesidad de continuar profundizando en los temas de aprendizaje y enseñanza. Futuras investigaciones deberán profundizar también en aspectos tales como la motivación, los valores y actitudes. Es importante incluir en futuras investigaciones el análisis de la transferencia a la vida diaria de las mejoras intelectuales en los estudiantes.

4 Agradecimientos

La investigación que se ha expuesto en las líneas anteriores se pudo llevar a cabo, en gran medida, gracias al apoyo que brindó la Universidad Autónoma Metropolitana (Unidad Azcapotzalco) de la ciuidad de México. El autor de esta investigación agradece a la Institución todas las facilidades recibidas para la aplicación del Programa SAM.

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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

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Resumen. En este trabajo se presenta una propuesta de aplicación docente de la teoría de la elaboración de Reigeluth y Stein, mediante la utilización del programa informático CmapTools. Dado que dicho programa permite construir mapas conceptuales y nexos de unión entre ellos de manera extraordinariamente sencilla, se propone su utilización para construir mapas de experto tridimensionales: es decir, mapas conceptuales que, además de representar diversos tipos de contenidos, incorporan una dimensión más de jerarquización. Este tipo de mapas permiten así simular los diversos "niveles de elaboración" correspondientes a una secuencia de aprendizaje. También permiten dar cabida a los Contenidos de Apoyo y a los Contenidos de Planteamiento que propone la teoría de la elaboración, así como otros elementos que enriquecen el diseño de una unidad didáctica (como las Preconcepciones más frecuentes que presentan los alumnos o la Explicación Causal Básica de los fenómenos físicos considerados).

1 La teoría de la elaboración: aplicaciones a la enseñanza de la Física

Una de las cuestiones didácticas que más preocupan a los docentes es cómo seleccionar, estructurar y secuenciar los contenidos de enseñanza de la forma más eficaz. Desde la Didáctica y la Psicología de la Instrucción se han desarrollado tradicionalmente diversas alternativas para organizar secuencias de enseñanza-aprendizaje, ya sea principalmente a partir del análisis interno del contenido a enseñar, o bien, a partir del análisis de las tareas que se pretende que el alumno sepa realizar al final del proceso. Dichas alternativas prescribían secuencias básicamente lineales en función de criterios de generalidad (desde los contenidos más generales a los más inclusivos); o bien en función de su complejidad (desde los aprendizajes más básicos o que requieren menos conocimientos previos a los más complejos). La teoría de la elaboración de Reigeluth y Stein (1983, 1987) constituyó, por el contrario, una propuesta integradora, basada en lo que ha dado en denominarse "secuenciación en espiral" del aprendizaje.

La teoría de Reigeluth justifica la importancia de secuenciar los contenidos y actividades de enseñanza-aprendizaje sobre dos análisis fundamentales: la reflexión sobre el contenido organizador y los diferentes niveles de elaboración en que se debe vertebrar la secuencia de aprendizaje. Cada uno de estos niveles comienza con una "visión panorámica" (o epítome) de los contenidos más generales que posteriormente se pretende desarrollar con detalle. El epítome sintetiza aquellas ideas más generales en un mismo nivel que se retoma y consolida cada vez que se profundiza un poco más en los contenidos, de modo que las relaciones de conjunto siempre priman sobre los contenidos específicos del mismo. El alumno los identifica como partes de un todo estructurado, puesto que la explicación del profesor describe sucesivas aproximaciones que no los agota, uno a uno, en su primera presentación. Cada una de estas fases de acercamiento del "zoom" al contenido específico de la materia supone pues un nivel mayor de elaboración de aquel epítome inicial.

Por otra parte, cada epítome es un contenido de enseñanza en sí mismo, estructurado en torno a un contenido organizador, como ya hemos dicho, pero sobre todo presentado en un nivel de aplicación lo más práctico posible. Aquí reside la mayor dificultad de su confección, por cuanto el alumno necesita un primer conocimiento experiencial y concreto de todo el conjunto, que sirva de anclaje para las posteriores profundizaciones en la jerarquía epistemológica de la materia. Cada vez que culminemos una fase más de profundización ("elaboración"), deberemos insistir en las relaciones que presenta con el plano general de conjunto, con lo que este se enriquece y extiende. Se trata del "epítome ampliado". Al final de los sucesivos epítomes obtendremos, por tanto, un "epítome final", donde aquella dimensión fundamentalmente práctica del primero aparece ya reformulada con múltiples relaciones semánticas (más abstractas) que se han ido generando en el proceso. En la figura 1 se presenta un esquema en el que se sintetizan los principales componentes didácticos que acabamos de comentar.

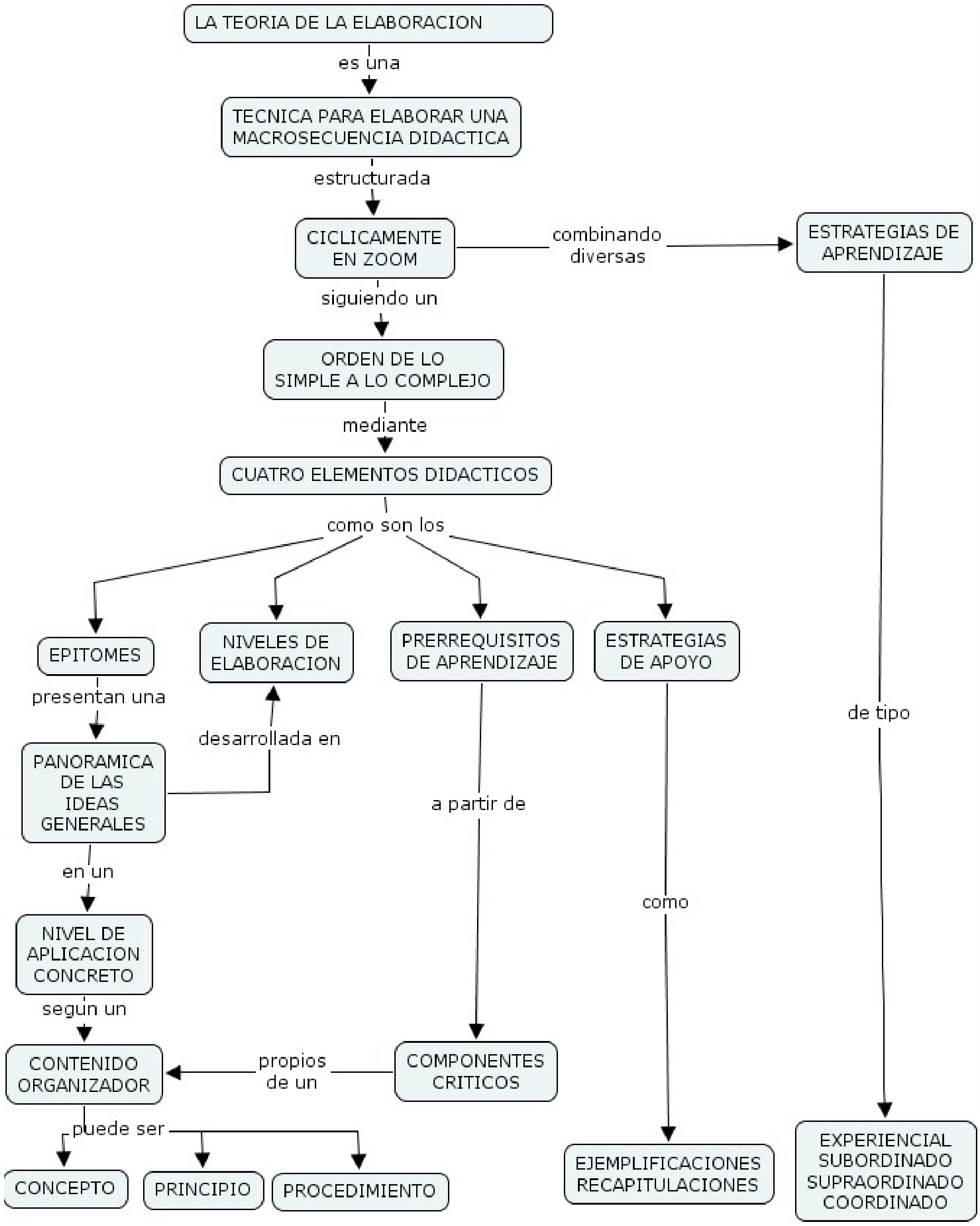

Figura 1. Componentes didácticos de la teoría de la elaboración (realizado en CmapTools)

La teoría de la elaboración contiene, en definitiva, aportaciones de gran interés para la secuenciación de contenidos en los diseños curriculares (Coll, 1987; Coll y Rochera, 1990). En el marco de la enseñanza de la ciencia, ofrece además un soporte teórico para propiciar ese progresivo encuentro entre el escenario cotidiano y científico que requiere el tratamiento de las teorías implícitas. Sin embargo, no tiene en cuenta cómo diseñar los procesos y estrategias que conducen al cambio conceptual, en materias donde este aspecto tiene tanta relevancia, como ocurre en la Física.

Para operativizar este objetivo, la principal innovación que hemos propuesto se fundamenta en la consideración de los fenómenos físicos (en lugar de los conceptos o principios) como un nuevo contenido organizador de las secuencias de enseñanza-aprendizaje. Desde nuestro punto de vista, el planteamiento de los fenómenos físicos como eje que vertebra la secuencia de instrucción, es el mejor recurso para facilitar el enriquecimiento de los conocimientos que van siendo construidos por los alumnos, desde el escenario cotidiano hacia el escolar y científico; así como para incidir sobre los sesgos inferenciales que intervienen en las explicaciones causales que el alumno elabora sobre dichos fenómenos, a lo largo de toda la secuencia elaborativa. Esta hipótesis se asienta sobre tres consideraciones generales:

a) En primer lugar, *la construcción del epítome a partir de los fenómenos físicos* que se van a abordar, no sólo promueve el *conocimiento experiencial* (de acuerdo con uno de los presupuestos de la teoría de Reigeluth), sino que garantiza además un "contexto de descubrimiento", fundamental para la generación de conflictos empíricos y conceptuales, desde los primeros momentos del proceso de aprendizaje.

Tomando como ejemplo un diseño didáctico sobre Termodinámica, el epítome inicial podría centrase en los fenómenos de dilatación y cambio de estado que experimentan los cuerpos al variar su temperatura. El proceso de cambio conceptual requiere que el análisis de estos fenómenos físicos por parte del alumno esté contextualizada en un sistema y desde un modelo teórico adecuado al modelo mental que es capaz de construir en cada momento del aprendizaje; de manera que sea posible la producción de conflictos cognitivos con sus preconcepciones implícitas. Algunas de las más relevantes, en este caso, podría sintetizarse por ejemplo en la idea de que la temperatura del cambio de estado depende de la cantidad de sustancia o de la intensidad del foco calorífico. Los contenidos conceptuales de apoyo necesarios para poder realizar los nuevos aprendizajes de una manera significativa (temperatura, termómetro, estados de la materia…) se introducen en este momento de un modo "no rigurosamente científico", sino en cuanto conocimientos cotidianos que posteriormente se irán reelaborando.

b) En segundo lugar, el diseño de secuencias de contenidos en diferentes niveles de elaboración debería tener en cuenta la consideración de sistemas, relaciones legales, explicaciones y modelos teóricos progresivamente más complejos. Así, en nuestro ejemplo de Termodinámica, el modelo físico que el alumno puede elaborar en las primeras fases se basa en una representación mental de los cuerpos, formados por partículas puntuales en movimiento, unidas entre sí por algún tipo de enlace de intensidad variable. Posteriormente, una vez introducido en el segundo epítome nuevos fenómenos relacionados con la transferencia de calor (conducción, radiación y convección) y los "gases ideales" en el tercero (procesos isocoros, isobáricos, isotérmicos y adiabáticos), el alumno debe reconstruir una nueva representación mental que incorpore el modelo de los "gases perfectos".

Esta secuencia potencia el desarrollo de tres vectores básicos en la construcción del conocimiento científico. El vector *de lo simple a lo complejo*, y *de lo concreto a lo abstracto*, supone que el aprendizaje no consiste en incorporar sin más nuevos conocimientos ni en sustituir unos conceptos erróneos por otros verdaderos, sino en la constante reelaboración de las relaciones causales y legales entre los conceptos de una teoría, desde las más simples o unidireccionales, hasta relaciones más complejas y sistémicas. El vector *de lo implícito a lo explícito* requiere analizar, confrontar y verbalizar los modelos internos que representan la realidad física para someterlos a un proceso de reelaboración consciente. A estos ejes, podríamos, en algunos casos específicos, añadir un cuarto: el vector *del realismo al perspectivismo*, que implica la reflexión sobre explicaciones y modelos alternativos de construcción del conocimiento científico (Rodrigo y Correa, 1999).

c) Por último, la vertebración del aprendizaje en torno a los fenómenos como contenido organizador, facilita la inclusión de tres actividades específicamente dirigidas a confrontar las explicaciones causales y los modelos mentales que construyen los alumnos.

En primer lugar, el desarrollo del epítome, debe comenzar con actividades de observación de los rasgos esenciales que se dan en los fenómenos físicos y *discusión* sobre las posibles explicaciones causales. La *explicación causal básica* (E.C.B.) debe fundamentarse en el *modelo científico* más cercano al *modelo mental* que el alumno es capaz de construir en cada fase del aprendizaje o nivel de elaboración. Por ejemplo, a partir de la observación del fenómeno "cambio de estado", la E.C.B. que el alumno debe inducir con la ayuda del profesor, en el primer nivel de elaboración, se fundamenta en la idea de que cuando un cuerpo aumenta de temperatura, se incrementa el movimiento de sus partículas hasta un punto en que se debilitan los enlaces que las mantienen unidas y se produce el cambio de estado. Una experiencia práctica, en este sentido, podría comenzar sometiendo un recipiente con un trozo de hielo, otro de estaño y otro de plomo (que poseen distintos puntos de fusión) a la llama de un mechero hasta conseguir su fusión. La pregunta que deben tratar de contestar los alumnos sería "porqué se deshacen estos cuerpos", o "qué habrá pasado en su interior". La explicación causal básica que los alumnos deben tratar de descubrir, a partir de los rasgos perceptivos del fenómeno, es que al "darle energía calorífica", y aumentar en consecuencia su temperatura, las "partículas" del cuerpo (contenido de apoyo) vibran con más energía y se van separando entre sí (se dilata), hasta que disminuye tanto la interacción que mantiene unidas las partículas (otro contenido de apoyo) que acaba "deshaciéndose" el cuerpo.

Posteriormente, debemos promover actividades de *planteamiento inicial de leyes*, a partir de tareas que requieran el control de variables y la falsación de predicciones sobre el fenómeno. Para ello, es importante partir de la explicación de los cambios en los primeros niveles de elaboración, para ayudar luego progresivamente al alumno a reconocer las relaciones proporcionales, de interdependencia, etc., aunque aún no se lleguen a formular matemáticamente como leyes. Siguiendo con el mismo ejemplo, sobre la experiencia anterior, puesto que la temperatura debe ir aumentando, a medida que se proporciona energía al calentar, puede plantearse a los alumnos: ¿subirá siempre igual la temperatura?; ¿podría llegar a estabilizarse?; ¿cómo sería esto último posible? Se trata, en este caso, de sugerir una ley de la fusión: la constancia de la temperatura mientras dura ésta. Si, en cambio, se pretende sugerir la otra ley de la fusión (cada sustancia pura tiene su propio punto de fusión), se preguntará, por ejemplo, "¿por qué hay que elevar la temperatura más al plomo que al estaño, y más al estaño que al hielo?", sin necesidad de llegar, de momento, a respuestas completas.

Combinadas con las anteriores, un tercer tipo de actividades (que pueden ser cooperativas o de "lápiz y papel") estarían ya específicamente dirigidas a facilitar la toma de consciencia del conflicto entre la teoría causal (hasta ahora "implícita") y las nuevas explicaciones causales de los fenómenos. El profesor debe aquí valorar si es conveniente desvelar todas o algunas de las respuestas correctas o, por el contrario, es más útil, didácticamente, dejar la solución correcta para ir dándola a lo largo del desarrollo posterior de los contenidos de la unidad didáctica (aspecto que, hábilmente utilizado, puede incrementar la motivación en el alumno). De cualquier forma, en la puesta en común el profesor debe formular explícitamente las teorías implícitas que hayan reflejado los alumnos a través de sus respuestas. Sólo así conseguiremos promover también con nuestra secuencia elaborativa un auténtico cambio conceptual.

2 Mapas de experto tridimensionales

Recientemente, hemos operativizado y apoyado todas estas orientaciones con materiales didácticos en diferentes macrosecuencias de aprendizaje para cada una de las ramas de la Física en la Educación Secundaria (Pérez y cols., 1999, 2000, 2001). En dichos trabajos (que fueron financiados por el CIDE y distinguidos con el 2º Premio Nacional de Investigación Educativa 1998), hemos incorporado una nueva herramienta, los mapas tridimensionales, que facilitan la operativización de este tipo de secuencias didácticas a la enseñanza de la Física. Los materiales ya publicados pueden consultarse en la dirección electrónica http://grupoorion.unex.es/pdf/libro.pdf

Como acabamos de ver, la elaboración de secuencias de enseñanza-aprendizaje basadas en la teoría de la elaboración debe partir de un análisis sistemático acerca de las relaciones epistemológicas entre los diversos contenidos científicos de enseñanza. Dicha reflexión debe apoyarse en un sistema de representación gráfica. Aunque podemos utilizar variadas técnicas de representación como los diagramas de flujo, los organigramas o los cuadros sinópticos, la más potente y desarrollada para este fin y con las que mejores resultados hemos conseguido en nuestra práctica docente es sin lugar a dudas los *mapas conceptuales*.

Un mapa conceptual es un procedimiento gráfico para explicitar nuestro conocimiento sobre conceptos y relaciones entre los mismos en forma de proposiciones verbales. Para Novak y Gowin (1984) no sólo es un instrumento útil para la instrucción y evaluación de contenidos conceptuales, sino también para facilitar el análisis previo de las relaciones significativas entre los mismos. Este análisis epistemológico requiere, además de un amplio trabajo de estudio e investigación científica, un proceso de explicitación de la *estructura lógica* de la materia. La utilización para este fin de una estrategia de representación como el mapa conceptual nos aporta tres soportes fundamentales en el proceso de reflexión didáctica antes de iniciar el proceso de enseñanza:

- permite confrontar visualmente la organización de los contenidos de la materia, de modo que se aprecian con más claridad las posibles lagunas y relaciones epistemológicas menos consistentes, que puedan restarle potencialidad significativa;
- facilita una organización jerárquica, que marca los posibles caminos didácticos que el profesor puede seguir desde los conceptos más generales hasta los más específicos; y, sobre todo,
- se convierte en un marco de diálogo, en una herramienta de trabajo en equipo, que permite confrontar los contenidos semánticos explícitos o implícitos sobre los que cada uno organiza la enseñanza.

Esta última ventaja es quizá la más relevante de cara a potenciar actitudes y estrategias de reflexión colaborativa del profesorado. Una vez que se domina la técnica del mapa, su elaboración se convierte en un "puzzle de conceptos" donde cada profesor puede confrontar su visión del contenido con la de otros compañeros, también especialistas en la materia (o con la de los alumnos).

La utilidad de esta herramienta puede llegar, sin embargo, más allá del análisis conceptual de los contenidos de enseñanza. Como ya hemos comentado, resulta muy enriquecedor que el profesor de Ciencias analice, no sólo una representación de los "conceptos" que organizan la materia, sino también de los "principios", "procedimientos" y otros contenidos, no estrictamente conceptuales. En este sentido, no deberíamos hablar tanto de "mapas de conceptos" en general como de *mapas de experto* de muy diferente tipo, en función del análisis de contenido que se pretende primar, es decir, del *contenido organizador* (Reigeluth, 1983).

Por otro lado, la utilización de soportes informáticos interactivos, de carácter gráfico, ha posibilitado otras ventajas en su aplicación al diseño curricular. Como acabamos de ver, el mapa conceptual tradicional sintetiza el contenido en función de una dimensión vertical (correspondiente a las relaciones de pertenencia semántica entre cada concepto y otros más generales a los que se subordina) y otra horizontal (que permite visualizar aquellos que se relacionan en un mismo nivel jerárquico). Lo que hemos denominado *mapa de experto tridimensional* (Pérez y cols., 1998, 1999), facilita además al profesor la representación en un tercer vector: la "profundidad" de los contenidos, es decir, los diferentes niveles de complejidad que podemos establecer en la secuencia instruccional.

Para ello, inicialmente utilizamos el programa informático comercial FlowCharter 6.0 que permite combinar dos tipos de enlaces entre los contenidos representados. En primer lugar, las tradicionales líneas etiquetadas verbalmente que unen los diferentes contenidos entre sí (enmarcados generalmente en rectángulos o elipses) constituyen el soporte gráfico de la dimensión vertical y horizontal, antes mencionada. En segundo lugar, algunos de esos mismos contenidos (cuyos marcos aparecen además sombreados), se convierten en un enlace de "profundidad" que conecta con otro mapa, y permite al usuario "navegar" de uno a otro, sin salir del mismo documento. En la figura 2 se presenta el *mapa-llave* de la macrosecuencia de Termodinámica implementada con esta aplicación informática y en la 3, a modo de ejemplo, la síntesis del tercer nivel de elaboración. En esta última puede observarse que los "saltos" que están permitidos se corresponden con los enlaces posibles desde dicha síntesis que aparecen en el mapa-llave.

Volviendo a las aplicaciones de la teoría de la elaboración, la principal ventaja didáctica de este instrumento reside, pues, en su doble capacidad de representación. Por un lado, permite jerarquizar varios mapas en niveles sucesivos de complejidad, permitiendo al profesor simular una representación en "espiral" en niveles de elaboración, similar a la propuesta de Reigeluth. Por otro lado, esta versatilidad le convierte en el mapa de experto por antonomasia, dado que facilita la integración en un mismo soporte de diferentes técnica para representar contenidos (mapas conceptuales, mapas de principios, diagramas de flujo...).

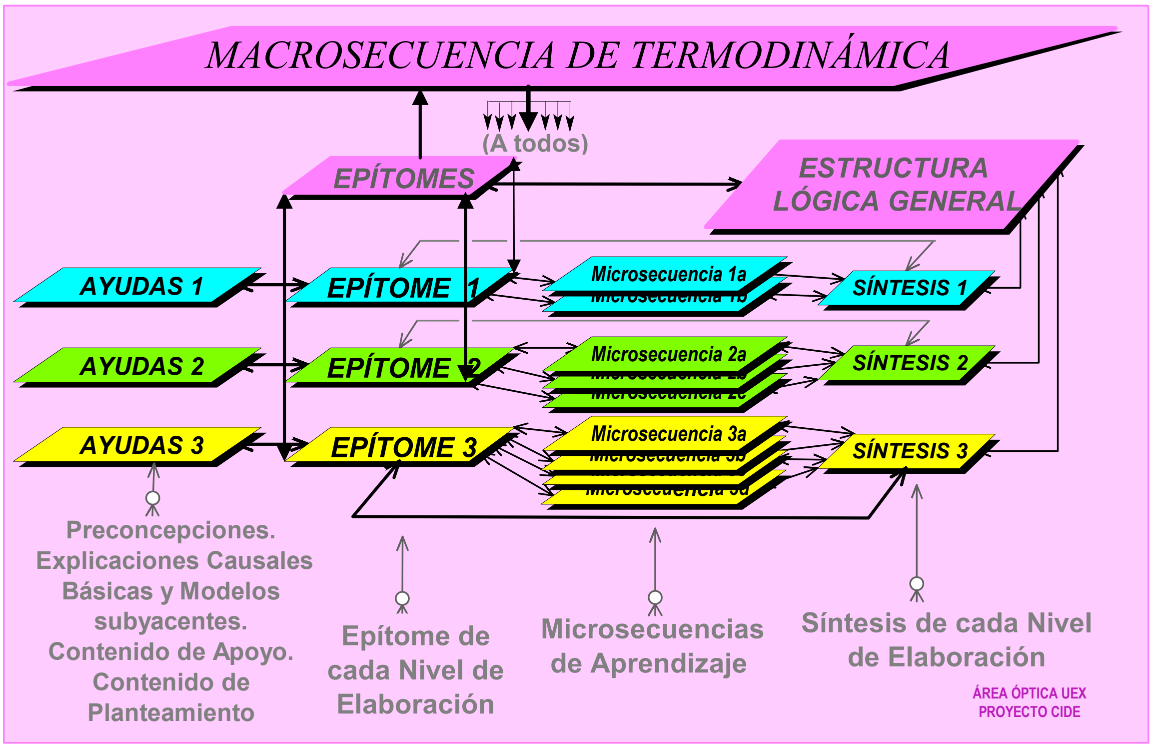

Figura 2. Mapa-llave de la Macrosecuencia Instruccional de Termodinámica (realizado en FlowCharter 6.0)

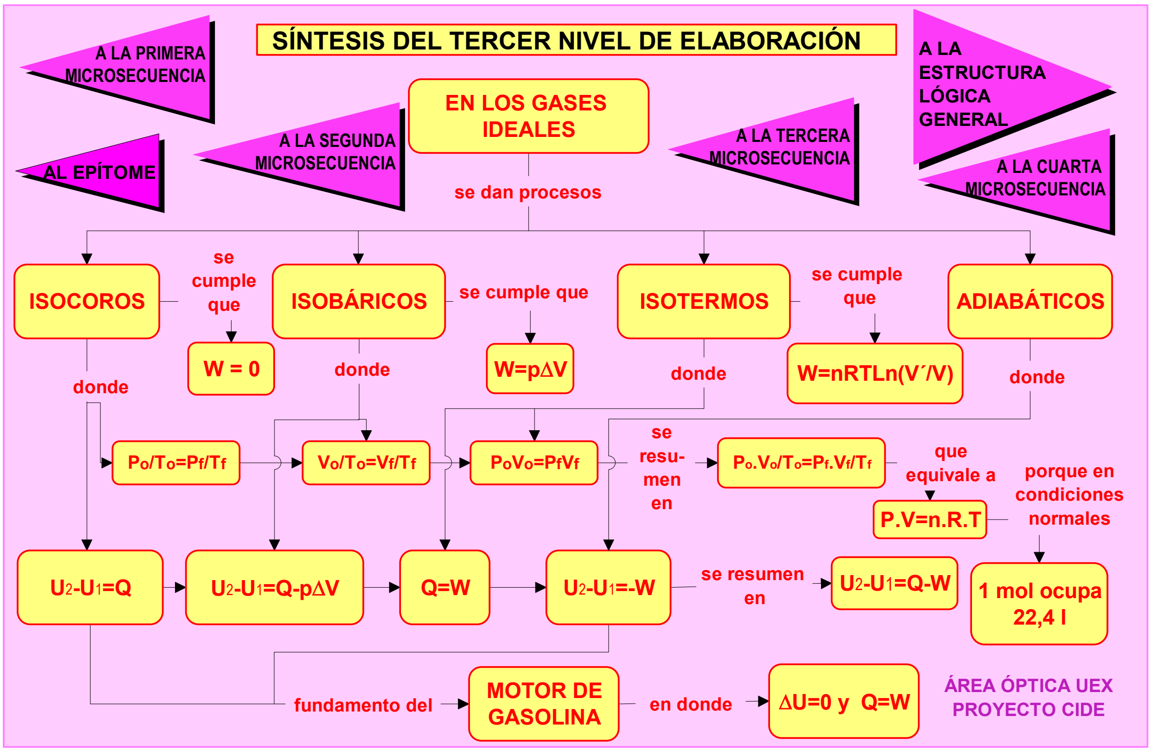

Figura 3. .Síntesis del tercer nivel de elaboración de la Macrosecuencia Instruccional de Termodinámica (realizado en FlowCharter 6.0)

3 Aplicaciones de los mapas tridimensionales al diseño de una unidad didáctica de Termodinámica: resultados de investigación

Con objeto de estudiar empíricamente las posibles utilidades didácticas de los mapas tridimensionales seleccionamos un grupo de profesores de Física de 4º de la E.S.O. Nuestra hipótesis era que la confección de una Unidad didáctica siguiendo las orientaciones metodológicas anteriores y con el apoyo de los mapas tridimensionales, tendría efectos positivos sobre el aprendizaje de los alumnos, particularmente en la modificación de preconcepciones erróneas.

En la investigación participaron 5 profesores y 341 alumnos, de diferentes institutos de la provincia de Badajoz. Cada profesor trabajaba con 3 grupos-clase en sus respectivos centros escolares. Mediante un procedimiento aleatorio, 2 de esos grupos fueron asignados a la condición experimental (secuencia de instrucción, basada en la teoría de la elaboración, y diseñada con mapas tridimensionales) y 1 a la de control (secuencia de instrucción según la metodología habitual del profesor). La evaluación inicial nos obligó a desestimar un grupo que no cumplían suficientes condiciones de homogeneidad, razón por la cual uno de los profesores no tuvo grupo de control (quedando, por tanto, 10 Grupos Experimentales y 4 de Control).

Se elaboraron tres materiales de evaluación: una prueba objetiva con problemas para el análisis de teorías implícitas (T.IMP.); otra sobre comprensión de conceptos científicos (COMP.); y otra con problemas de interpretación de fenómenos y de aplicación a situaciones cotidianas (APLIC.). Además, cada profesor realizó una valoración tradicional del rendimiento en la materia mediante dos pruebas elaboradas “ad hoc” por ellos mismos: una prueba de ejecución con problemas de Física que requieren cálculo y soluciones numéricas (RP) y una prueba-examen general (CAL.).

La siguiente tabla recoge los resultados obtenidos. Como puede observarse, la puntuación media (GLOB) obtenida en las diversas pruebas de evaluación inicial por los grupos Experimentales (EXP) y de Control (CONTR) resultó prácticamente idéntica (0.1 puntos de diferencia). La medición postest, una vez finalizada la unidad didáctica, reveló una mejora significativa en todos los grupos evaluados, lo cual es también una prueba de la aceptable calidad de los métodos de instrucción que hasta entonces habían utilizado los profesores que participaron en la investigación. Sin embargo, los resultados muestran mayores incrementos (hasta 1.0 punto más) en los grupos en los que se desarrollaron las actividades basadas en la teoría de la elaboración para la enseñanza de la Física. Las diferencias resultaron entre los grupos experimentales y control resultaron significativas en la prueba específica de teorías implícitas (TI: $t=2.18$; $p<0.05$), en la asimilación de conceptos científicos (CC: $t=5.59$; $p<0.01$) y en la prueba de aplicación a situaciones cotidianas (A: $t= 4.60$; $p<0.01$).

GRUPOS	PRETEST						POSTEST					
	T.IMP.	COMP.	APLIC.	RP	CAL.	**GLOB.**	T.IMP.	COMP.	APLIC.	RP	CAL	**GLOB.**
Experimental 1	4,2	5,0	4,9	5,0	5,9	5,0	4,6	6,7	7,7	7,3	7,7	6,8
Experimental 2	4,0	5,1	5,1	4,9	5,8	5,0	6,8	7,7	7,2	7,4	7,5	7,3
Experimental 3	4,2	4,5	4,3	4,7	5,5	4,6	7,0	7,6	7,3	7,1	8,1	7,4
Experimental 4	3,8	4,9	5,0	5,0	6,0	4,9	7,4	7,7	6,7	7,4	8,0	7,4
Experimental 5	4,4	4,9	4,8	5,1	5,9	5,0	7,3	7,5	7,7	7,8	7,6	7,6
Experimental 6	4,3	4,6	4,7	4,7	5,4	4,7	7,1	7,6	7,7	7,3	7,5	7,4
Experimental 7	4,3	4,8	4,7	4,9	5,7	4,9	7,3	8,0	7,1	7,2	7,8	7,5
Experimental 8	4,2	4,6	4,9	5,2	5,7	4,9	7,6	7,5	7,0	7,7	8,2	7,6
Experimental 9	3,8	4,9	4,7	4,8	5,6	4,8	6,8	7,5	7,4	7,7	8,0	7,5
Experimental 10	4,2	4,7	4,3	4,9	5,6	4,7	7,1	7,2	7,2	7,3	8,0	7,3
Media de los G. Exp.	4,1	4,8	4,7	4,9	5,7	4,9	6,9	7,5	7,3	7,4	7,8	7,4
Control 1	3,6	4,9	5,0	5,0	5,7	4,8	5,8	6,5	6,9	6,6	6,8	6,5
Control 2	4,2	4,7	5,3	5,0	6,1	5,1	5,8	6,3	6,8	6,7	6,6	6,4
Control 3	3,7	4,8	4,8	5,0	6,0	4,8	5,8	6,3	6,1	6,4	6,9	6,3
Control 4	4,6	5,0	4,9	5,1	6,0	5,1	6,2	6,8	6,1	6,5	6,9	6,5
Media de los G. Cont.	4,0	4,8	5,0	5,0	5,9	5,0	5,9	6,5	6,5	6,5	6,8	6,4
Diferencia de las medias	0,1	0,0	-0,3	-0,1	-0,2	**-0,1**	1,0	1,0	0,8	0,9	1,1	**1,0**

El informe completo acerca de la metodología (participantes, diseño, instrumentos y procedimientos), los resultados y las conclusiones de la investigación realizada puede consultarse en la dirección electrónica http://grupoorion.unex.es/didactica/complemento_comunicacion_al_cmc.doc

4 Nuevas líneas de investigación: aplicaciones del programa informático CmapTools

Los mapas de experto tridimensionales constituyen, en definitiva, una propuesta innovadora con interesantes aplicaciones al diseño curricular en general, y a la enseñanza de la Física en particular. El aprovechamiento de herramientas informáticas que faciliten la construcción e integración de mapas constituye una ventaja esencial para el desarrollo y la comunicación en red de diseños instruccionales. Algunos nuevos programas de diseño gráfico ofrecen interesantes alternativas para conectar mapas entre sí, como proponíamos anteriormente, al tiempo que facilitan la comunicación entre los diseñadores y usuarios. En concreto, la herramienta informática CmapTools (Cañas et al., 2004) aporta unas posibilidades de compartir estos mapas con otros compañeros de cualquier parte del mundo que no eran contempladas en la aplicación informática anteriormente utilizada. Por esta razón, actualmente estamos trabajando en la utilización del programa informático CmapTools para construir mapas de experto tridimensionales, siguiendo las directrices anteriores. Nuestra aportación al uso de esta herramienta se centra en conectar los mapas simulando *niveles de elaboración*, además de introducir *contenidos de apoyo* y *de planteamiento*, así como conexiones con las *preconcepciones* mas frecuentes que suelen tener los alumnos.

La versión original de los mapas de experto tridimensionales realizados con la aplicación FlowCharter incluyendo un visor y las instrucciones de instalación que la hacen completamente operativa, puede obtenerse en nuestra dirección web: http://grupoorion.unex.es/didactica/premio.exe . Estos mapas, revisados y ampliados durante la realización de dos tesis doctorales son los que han sido "traducidos" a CmapTools y alojados en un nuevo servidor adquirido con este fin que se ha compartido en la red de servidores CmapServer bajo el nombre de *Grupo Orión-Universidad de Extremadura (España)*. En este mismo congreso se presentan otras dos comunicaciones más, a modo de ejemplificación de lo aquí expuesto. En la primera "Macrosecuencia instruccional de óptica confeccionada siguiendo las directrices de la teoría de la elaboración de Reigeluth y Stein e implementada en el programa Cmaptools" se hace principal hincapié en el proceso de elaboración de la macrosecuencia instruccional y en la segunda "Macrosecuencia instruccional de electricidad confeccionada siguiendo las directrices de la teoría de la elaboración de Reigeluth y Stein e implementada en el programa Cmaptools" se hace principal hincapié en el proceso de elaboración de unidades didácticas a partir de la macrosecuencia instruccional. Ambas han sido implementadas en CmapTools y se encuentran compartidas a través de CmapServer.

5 Agradecimientos

Queremos expresar nuestro agradecimiento al Centro de Investigación y Documentación Educativa (CIDE) del Ministerio de Educación y Ciencia (MEC) por la financiación que hizo posible el desarrollo de los trabajos de investigación que permitieron elaborar los materiales didácticos aquí descritos; a la Universidad de Extremadura en cuyo seno se han llevado a cabo estas investigaciones y a la Consejería de Educación, Ciencia y Cultura de la Junta de Extremadura por su colaboración en la difusión de los resultados obtenidos mediante la publicación de un libro que fue distribuido gratuitamente a todos los centros de Educación Secundaria de la región.

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Concept Maps: Theory, Methodology, Technology
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A. J. Cañas, J. D. Novak, F. M. González, Eds.
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EL MAPA CONCEPTUAL COMO ELEMENTO FUNDAMENTAL EN EL PROCESO DE ENSEÑANZA-APRENDIZAJE DE LA FÍSICA A NIVEL UNIVERSITARIO

Ramírez de M. María; Sanabria Irma. Universidad Nacional del Táchira

Resumen. Este trabajo forma parte de iniciativas desarrolladas en la Universidad Nacional Experimental del Táchira UNET, para enfrentar las dificultades que los alumnos de Física I tienen en general para el logro de un aprendizaje significativo.
Para ayudar a resolver estos problemas, se propició en la UNET, durante siete lapsos académicos consecutivos la incorporación gradual de la herramienta heurística de los Mapas Conceptuales al proceso de enseñanza-aprendizaje de Física I, trabajando con aproximadamente 180 alumnos cada semestre. Los resultados obtenidos permitieron hacer sucesivas modificaciones hasta incorporar los mapas conceptuales como elemento básico de la estrategia general de trabajo en esa asignatura. Para ello fue necesario diseñar materiales instruccionales y experiencias de aprendizaje, que facilitaran a profesores y alumnos el manejo de esta herramienta heurística para la organización y construcción del conocimiento.
Se reporta el uso dado a los mapas conceptuales en los cursos de Física I en la UNET, y estrategias concretas para el desarrollo de algunos temas de esa asignatura. Se concluye que a pesar de las dificultades con grupos de 45 estudiantes para construir individualmente Mapas Conceptuales, éstos son valiosos para mejorar la comprensión y facilitar la construcción del su propio conocimiento, en la medida en que el alumno, en el proceso de enseñanza-aprendizaje, tenga la oportunidad de usarlos, analizarlos, cuestionarlos, o mejorarlos.
Algunos alumnos aprenden a diseñar mapas para construir su conocimiento, pero generalmente los prefieren para organizar y comprender información. Los profesores por su parte los usan mayoritariamente como organizadores del conocimiento.

1 Introducción

En la búsqueda de soluciones a los innumerables problemas que presentan los alumnos para el aprendizaje de la Física se ha detectado que los alumnos de la UNET tienen poco interés por las asignaturas de Ciencias Básicas y un manejo muy poco adecuado de habilidades necesarias para el pensamiento científico (Ramírez de M., 1995). Uno de los problemas más importantes, se evidencia en las dificultades que tienen los alumnos 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 los conceptos y tienen un manejo pobre de técnicas de representación, información y resumen.

Se sabe que 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 que el aprendizaje puede ser facilitado si los profesores ayudan a los alumnos a emplear 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 estos problemas. Por ello la autora diseñó una estrategia general de trabajo que permitiera incorporar los Mapas Conceptuales al proceso de enseñanza-aprendizaje de la Física, de manera que los alumnos pudieran comprender más fácilmente la materia y utilizar esa herramienta para la construcción de su propio conocimiento.

2 Mapa Conceptual y sus Usos

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 (Fig.1). 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 actualmente muchos usos. A pesar haber sido concebido originalmente por Novak como herramienta heurística a ser utilizada por el alumno para captar el significado de una estructura conceptual, 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 puede ser usada por los alumnos para presentar sus trabajos. Actualmente se desarrollan esfuerzos para construir mapas dinámicos (Novak, 2004) y facilitar el aprendizaje cooperativo a través de la red.

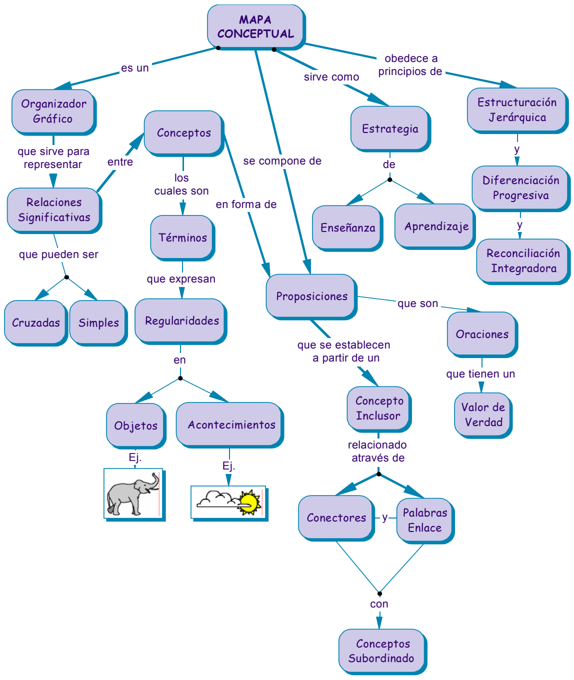

Figura 1. Mapa Conceptual del Mapa Conceptual;

Actualmente en la UNET los profesores comienzan a usar los mapas conceptuales también para orientar el proceso de diseño instruccional de los materiales que colocan en la red. La Figura 2 muestra un mapa de los diversos usos del Mapa Conceptual.

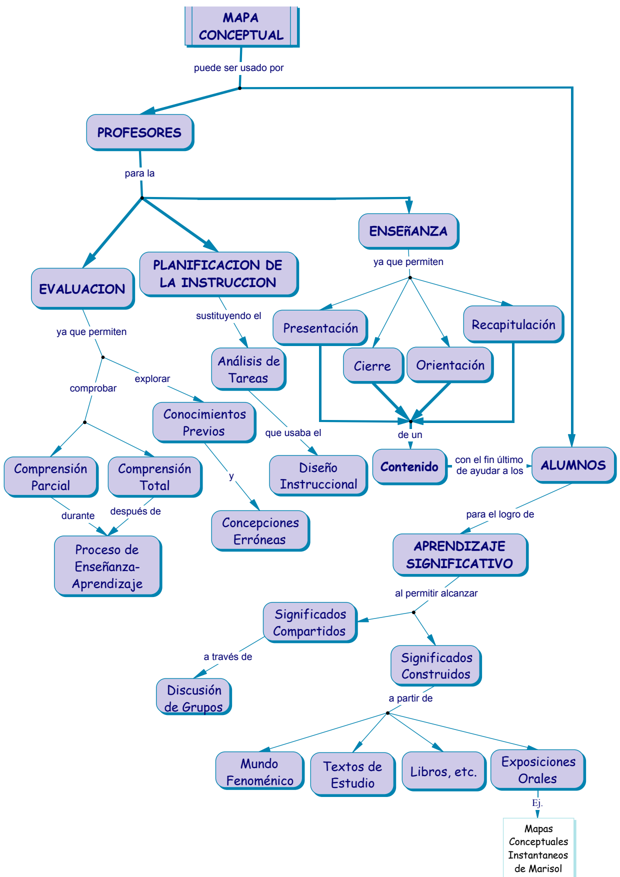

Figura 2. Usos del Mapa Conceptual

3 Proyecto de Incorporación de la Estrategia de los Mapas Conceptuales

El proceso para incorporar los mapas conceptuales a la metodología general de trabajo de la asignatura Física I se ha desarrollado a lo largo de siete semestres consecutivos. Se reportan dos grandes etapas. I.- El proceso de diseño instruccional de la estrategia. II.- la etapa de implantación. Los principales aspectos de este proceso se resumen en la Figura **3**. Se detallarán sólo algunos aspectos importantes para posteriormente explicar las estrategias específicas diseñadas

3.1 Etapa I: Diseño Instruccional de la Estrategia de Aprendizaje

La Asignatura Física I, en la UNET se dicta a nivel del segundo semestre del ciclo básico, con una carga de seis horas semanales durante quince semanas. El laboratorio es considerado materia aparte. Las secciones son de 45 alumnos. Generalmente cada semana se cubre un tema diferente. La metodología general de trabajo incluye, clases, demostraciones experimentales y talleres de resolución de problemas. La evaluación se hace con pruebas cortas y exámenes escritos. La presentación de la teoría, depende mucho del estilo del profesor y de la forma como ésta se enfoque. Es aquí donde se inició el trabajo con la incorporación de la herramienta "mapas conceptuales" para apoyar el desarrollo de la teoría y los procesos de comprensión y resolución de problemas. Para ello se diseñó una estrategia que permitiese:

- Iniciar al estudiante en la construcción de un mapa.
- Iniciar al estudiante en la comprensión de un mapa conceptual y de sus elementos.
- Construir mapas conceptuales de los temas que se quieren desarrollar.
- Demostrar cómo pasar de la teoría a un mapa que resuma lo planteado, o bien cómo a partir de un mapa es posible construir todos los conceptos relacionados con el tema.
- Demostrar la utilidad de los mapas para apoyar la resolución de problemas.

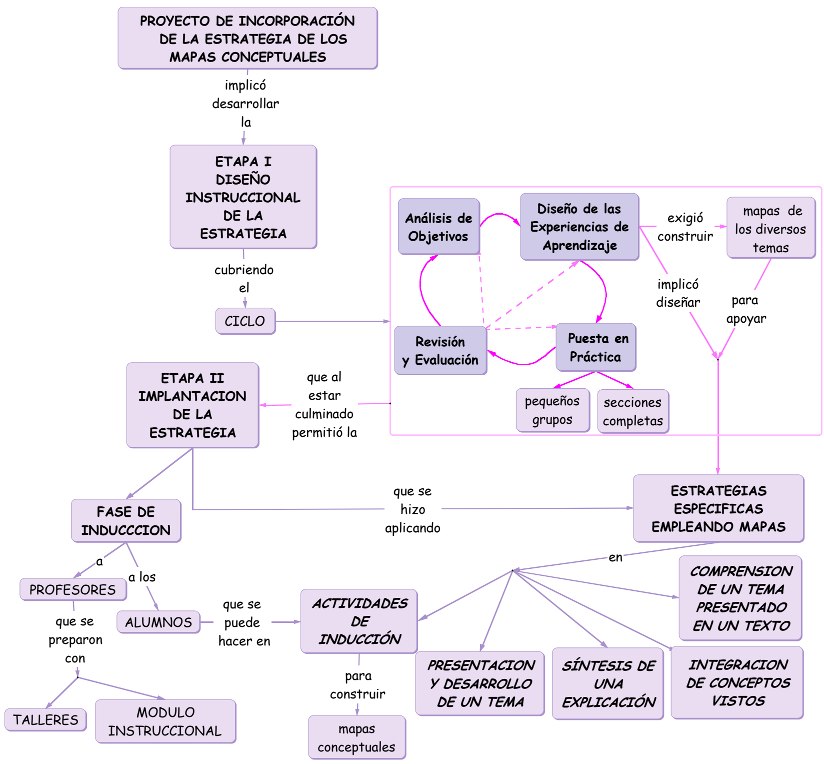

Figura 3. Proyecto de Incorporación de la Estrategia de Mapas Conceptuales

Se diseñaron estrategias específicas (Ver aparte 3.2.2) que permitiesen optimizar el uso de los mapas conceptuales para diversos fines. Se realizaron pruebas en pequeños grupos y a medida que se fueron haciendo las correcciones pertinentes, se probaron con secciones completas de 45 alumnos.

Las técnicas e instrumentos utilizados para evaluar la experiencia fueron: mapas conceptuales diseñados por los alumnos; cuaderno de registro de observaciones realizadas por el profesor y opiniones de los alumnos expresadas por escrito en cuestionarios semiestructurados. Se realizaron también entrevistas en profundidad cada semestre a pequeños grupos de alumnos. Se revisó también el rendimiento de los alumnos en aquellos temas en los cuales se habían empleado mapas. El análisis de toda esta información permitió hacer sucesivas modificaciones a las estrategias específicas y a los diversos mapas realizados por la autora, los cuales son usados como apoyo por los profesores en las distintas experiencias.

3.2 Implantación

3.2.1 Inducción

Para poder incorporar los mapas conceptuales a la metodología general de trabajo era fundamental que los profesores internalizaran las ventajas de trabajar con mapas conceptuales y dominaran la herramienta. Para ello fue necesario:

1. Realizar talleres para los profesores sobre mapas conceptuales y
2. Producir materiales instruccionales de apoyo.

La autora desarrolló un taller bajo un enfoque constructivista para que los profesores aprendieran el uso y manejo de los mapas conceptuales. Este taller se realiza con docentes de la UNET interesados en conocer esta estrategia. Un grupo creciente de profesores ha participado en ellos.

Por otra parte, se diseñó un módulo instruccional intitulado "***El mapa conceptual como herramienta heurística para facilitar la construcción del conocimiento***" (Ramírez de M, 2000). Este libro fue escrito por la autora para los docentes de la UNET quienes, por ser profesionales prestados a la docencia carecen de una formación pedagógica adecuada. El texto está diseñado bajo un enfoque constructivista en forma de diálogo permanente entre un profesor de la UNET, quien busca nuevas herramientas que faciliten su quehacer docente, y el profesor Novak quien va gradualmente ayudando al docente a construir su propio conocimiento sobre los mapas conceptuales. Los comentarios y dudas expresados por el profesor, pretenden hacer explícitas muchas de las preconcepciones de los docentes e inquietudes que habitualmente tienen sobre el aprendizaje, la herramienta de los mapas conceptuales y la manera de contribuir a lograr un aprendizaje significativo. Por su parte el otro personaje, Novak, aclara, orienta y le permite al docente ejercitar su metacognición. Además hay una caricatura de otro personaje, un *mapita* que cuestiona muchas cosas y se ríe de los esfuerzos del profesor por comprenderlo.

En la figura 4 se muestra a manera de ejemplo dos páginas de este libro.

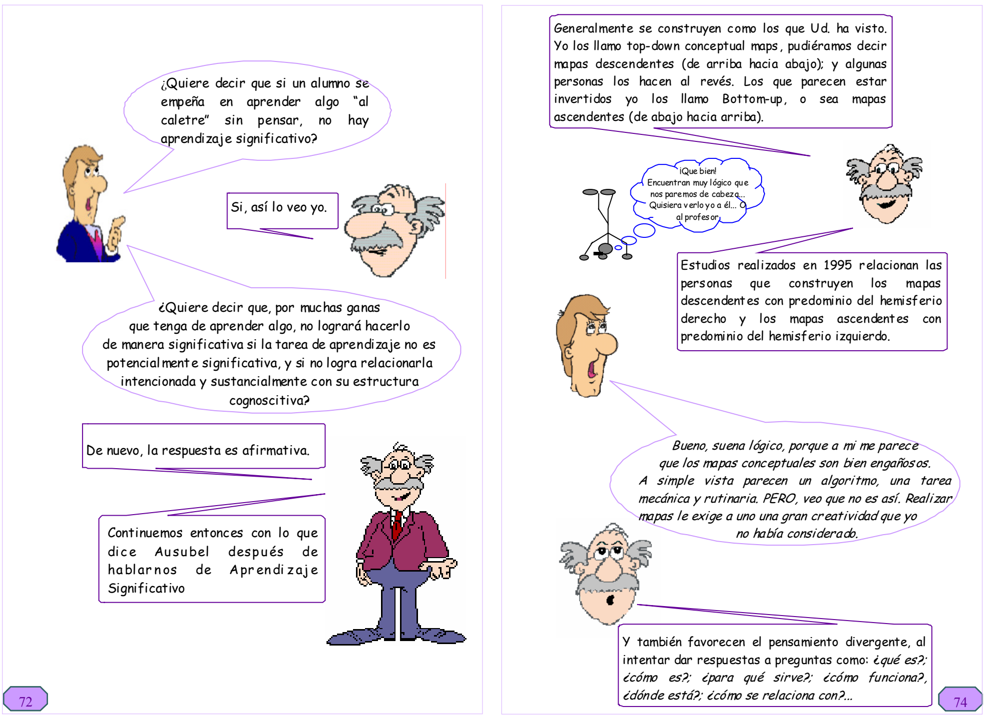

Figura 4. Muestra del libro *El Mapa Conceptual como herramienta heurística para facilitar el aprendizaje*

Este libro y los talleres de Mapas Conceptuales les permiten a los profesores de la UNET y otros institutos de educación, iniciarse en el uso de la herramienta de los Mapas Conceptuales.

3.2.2 Estrategias específicas para el aprendizaje de la Física I utilizando mapas conceptuales

Se describen a continuación algunas de las estrategias específicas que se usan actualmente en Física I. Debe quedar claro que en el desarrollo de cada tema se pueden usar los mapas de diversas maneras. Se presenta sólo una de las secuencias que usamos inicialmente para que el alumno se acostumbre a trabajar con M.C.

3.2.2.1 Introducción a los Mapas Conceptuales

- Se genera una discusión sobre lo que es un concepto, una proposición y sus elementos.
- Se les pide construyan un concepto sencillo de M.C. Luego se explica cómo representar una proposición cualquiera, con un mapa conceptual encerrando en algún tipo de recuadro los conceptos y enlazándolos con conectores (líneas a las que se les escribe la relación que hay entre los conceptos).
- Se les pide que construyan en silencio e individualmente un pequeño mapa conceptual acerca de un árbol o cualquier otro concepto inclusor sencillo. Se insiste en que incluyan, de ser posible qué es, para qué sirve, cómo está compuesto, cómo se relacionan entre ellos los elementos y todas las cosas que muestren la estructura conceptual que los alumnos tienen en relación con ese concepto.
- Se les pide que trabajando en parejas intenten leer el mapa del otro.
- Se hacen los arreglos necesarios a los conceptos o a las palabras enlaces o conectores que no se comprendan.
- Se discuten los mapas, sus elementos, características y se les pide construyan otro mapa conceptual de algún concepto básico de la Física. Estos se analizan y el profesor presenta el mapa hecho por un experto, para que vean *otra forma más* de estructurar la información. Se discuten las diferencias.

3.2.2.2 El Mapa Conceptual como organizador previo para presentar y desarrollar un tema

Esta semana se desarrollan dos temas y se usan los mapas de Movimiento en dos y tres dimensiones y el Movimiento Rectilíneo Uniforme (Ver Figuras 5 y 6) para presentar los conceptos y seguir la explicación.

Para el primer tema de Movimiento:

- Se presenta el mapa conceptual de Movimiento (Ver Figura 5).
- Se les pide que lean el mapa y expresen en sus propias palabras lo que entendieron.
- Se explica aquello que aún no comprendan los alumnos.
- Se les pide que construyan una definición de alguno de los conceptos que aparecen en el mapa para que vean que los conceptos básicos de cinemática ya están expresados en el M.C.
- Se resuelven problemas utilizando el mapa como apoyo (a manera de formulario) para aplicar los diversos conceptos.

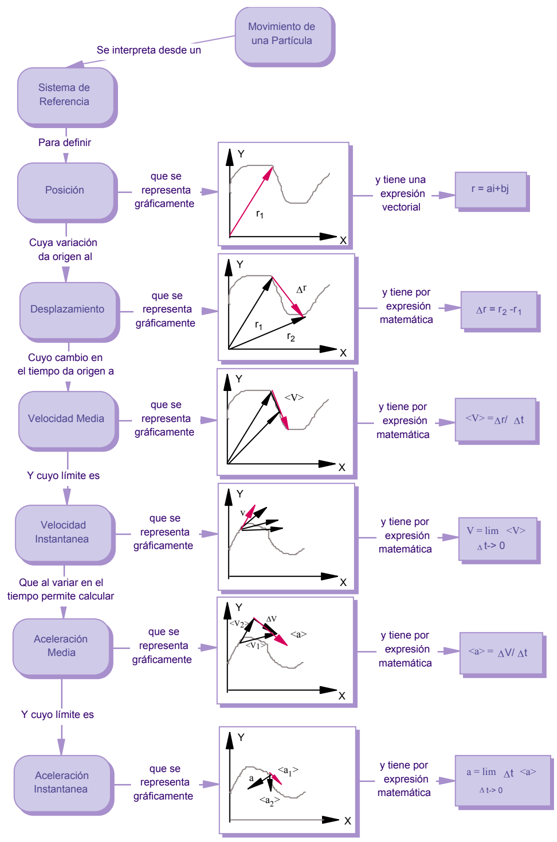

Figura 5. Movimiento en dos y tres dimensiones

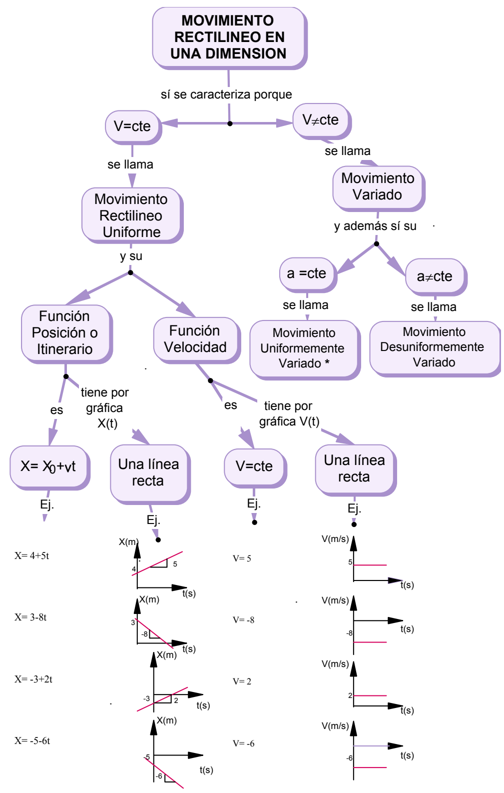

Figura 6. Movimiento Rectilíneo Uniforme

Para el tema de Movimiento Rectilíneo Uniforme:

- Se parte de las concepciones básicas de los alumnos para construir algunos conceptos básicos.
- Se presenta un mapa del Movimiento Rectilíneo hecho por el profesor (Figura 6). El profesor lee ordenadamente alguna de las proposiciones que aparecen en el mapa. Se hace que los alumnos lo lean y se comienzan a hacer preguntas sobre algunos conceptos y los que ellos construyeron anteriormente.
- Se resuelven problemas que requieran el uso de los conceptos expresados en el mapa y de su expresión matemática.
- En cada caso se insiste en los conceptos para que puedan ubicarlos en el mapa, comprender su definición y su expresión matemática y resolverlo efectivamente con la ayuda del mapa.

3.2.2.3 Uso del Mapa para hacer la Síntesis de una Explicación

- Se explica el Movimiento Uniformemente Variado sin usar el mapa organizador.
- Se trabaja en el pizarrón hasta construir las definiciones de las funciones posición, velocidad y aceleración en el movimiento uniformemente variado.
- Se explica la diferencia entre Movimiento Uniformemente Acelerado y Retardado y se dan ejemplos para que a partir de una función posición, velocidad o aceleración, el estudiante pueda construir la gráfica o viceversa.
- Finalmente se les muestra el mapa de Movimiento Uniformemente Variado (Figura 7) para sintetizar todo lo visto. Allí los alumnos encuentra las definiciones dadas y pueden reforzar sus conocimientos.
- Finalmente se resuelven ejercicios usando el mapa conceptual como apoyo.

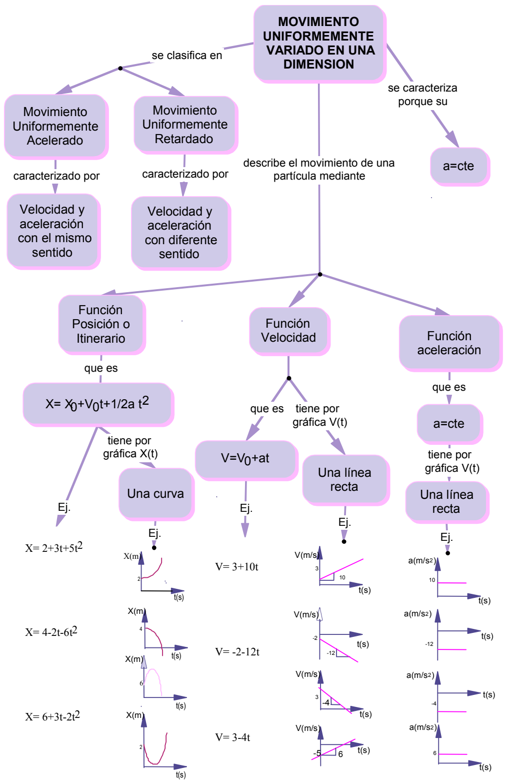

Figura 7. Movimiento Uniformemente Variado

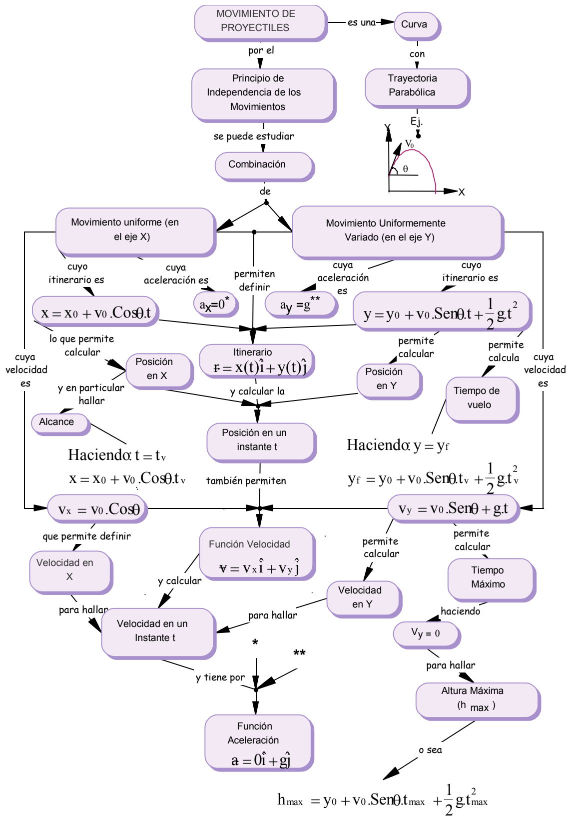

Figura 8. Movimiento de proyectiles

3.2.2.4 Uso del Mapa para Integrar Conceptos vistos

- Se introduce el tema de movimiento parabólico. Se explica que a partir del principio de independencia de los movimientos se define el movimiento de proyectiles como una combinación de dos movimientos (*horizontal*: rectilíneo uniforme; *vertical*: uniformemente variado) que ocurren simultáneamente.
- Se analiza lo que ocurre en cada eje y se les pide a los alumnos que describan, por separado, cuales son las funciones posición, velocidad y aceleración para estos dos movimientos.
- Se les pide que usando los M.C. de movimiento, hallen la posición, velocidad y aceleración de un cuerpo que se mueve a la vez en el eje x y en el eje y.
- Al descubrir el alumno que *pueden combinar* los dos mapas anteriores y escribir las funciones básicas correspondientes a este movimiento que combina los anteriores, se les entrega la Figura 8 y se discute. Posteriormente se hacen preguntas sobre los conceptos y se resuelven problemas.
- Se hace preguntas acerca de los diversos conceptos que aparecen en el mapa y se inicia la resolución de problemas.

3.2.2.5 Construcción de un mapa a partir de un texto escrito

- Para los temas sucesivos de Física se les pide a los alumnos que a partir de algunas clases y de textos que se les facilita por escrito, los estudiantes construyan sus propios mapas conceptuales y los entreguen como tarea.
- Se comienza con conceptos sencillos de alguno de los temas de Física. En todo caso siempre se discuten algunos de los mapas entregados por los alumnos. Luego se les da el mapa del profesor para que, sin ser "el mapa verdadero" al menos les sirva de referencia para compararlo con los suyos.
- En las últimas semanas del curso ya se les puede pedir que construyan una estructura conceptual completa de un tema.
- En todas las actividades se les enseña a usar el mapa como "formulario" inteligente que les permite recordar no solo las fórmulas sino los principios y teorías, que enmarcan el estudio de un determinado fenómeno y que por ende se pueden aplicar para resolver un problema.

4 Resultados y Conclusiones

- La experiencia se ha realizado en siete oportunidades con alumnos regulares de Física I. Se comenzó con cuatro secciones de las nueve habitualmente ofertadas a los alumnos. Gradualmente se han ido incorporando los otros profesores que trabajan en la misma asignatura.
- La *resistencia* que aún ofrecen algunos profesores a incorporar los M.C. a su metodología de trabajo, obedece a una orientación conductista tan marcada que les dificulta el contemplar nuevas posibilidades de acción, donde el alumno pueda construir más activamente su propio conocimiento.
- Las evaluaciones cualitativas realizadas a partir del análisis de los mapas conceptuales diseñados por los alumnos; el cuaderno de registro de observaciones realizadas por el profesor y las opiniones de los alumnos, permiten afirmar que la estrategia ha sido adecuada y se presenta como un elemento promisorio que contribuye al logro de un aprendizaje significativo de la Física.
- Al ser el Mapa Conceptual una herramienta que cada alumno usa de diversas maneras a lo largo del curso ha sido imposible establecer diferencias significativas entre los puntajes obtenidos por alumnos que han aprendido a usar mapas conceptuales y los de las otras secciones. Sin embargo, es opinión mayoritaria de los alumnos que la incorporación de los mapas conceptuales al trabajo de estudio y del aula les permite obtener fácilmente una visión global de cada tema tratado y entender las relaciones entre los distintos conceptos que lo conforman. Los estudiantes han manifestado su agrado por la claridad con la que los mapas pueden resumir toda la información de cada tema en particular. Además los usan como formulario para la resolución de problemas.
- Los mapas conceptuales por ser una ayuda visual son una herramienta poderosa para facilitarle a los alumnos la comprensión general de un tema y la relación entre los conceptos. Los mapas pueden ser usados, como se planteó anteriormente, de diversas maneras. Además los Mapas Conceptuales ayudan al estudiante a desarrollar su capacidad de síntesis.
- Se concluye que a pesar de que resulta difícil la construcción individual de Mapas Conceptuales en grupos de 45 estudiantes, éstos son valiosos para mejorar la comprensión y facilitar la construcción del su propio conocimiento, en la medida en que el alumno, en el proceso de enseñanza-aprendizaje, tenga la oportunidad de usar mapas propios o de expertos para, analizarlos, cuestionarlos, o mejorarlos.
- Los alumnos prefieren mayoritariamente los mapas para organizar y comprender información. Muchos continúan empleándolos en otras materias y manifiestan que esa herramienta les ha ayudado mucho a comprender algunos temas de Física II y Termodinámica. La mayoría de los profesores por su parte los usan mayoritariamente como organizadores del conocimiento para facilitar el aprendizaje en sus clases.
- La estrategia ha sido bien recibida tanto por los profesores como por los alumnos por lo que se recomienda continuar utilizándola y extender su uso a los demás temas de Física I.
- La herramienta CmapTools permite la realización de mapas conceptuales dinámicos y el acceso de los alumnos a la información a través de la red, pero debe recordarse que para contribuir con ello al logro de un aprendizaje significativo del alumno, los Mapas Conceptuales para organizar la información deben estar bien concebidos desde el punto de vista del diseño instruccional.

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LA TEORÍA DEL APRENDIZAJE SIGNIFICATIVO.

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Resumen. Se hace una revisión de la Teoría del Aprendizaje Significativo tratando en primer lugar su caracterización. Se delimitan sus conceptos-clave, analizando el significado del constructo "aprendizaje significativo", tanto desde la perspectiva ausubeliana, como atendiendo a distintas contribuciones que han enriquecido su sentido teórico y su aplicabilidad; así mismo, se repasan algunos de los aspectos más confusos relativos a su uso en el aula. Se analizan posteriormente algunas consecuencias derivadas de la consideración de esta teoría y se revisa a la luz de la Teoría de los Modelos Mentales (Johnson-Laird) y de la Teoría de los Campos Conceptuales (Vergnaud). Se concluye que la Teoría del Aprendizaje Significativo es aún hoy un referente explicativo de gran potencialidad y vigencia que da cuenta del desarrollo cognitivo generado en el aula.

Introducción

En 1963, Ausubel hizo su primer intento de explicación de una teoría cognitiva del aprendizaje verbal significativo publicando la monografía "The Psychology of Meaningful Verbal Learning"; en el mismo año se celebró en Illinois el Congreso Phi, Delta, Kappa, en el que intervino con la ponencia "Algunos aspectos psicológicos de la estructura del conocimiento".

Cuarenta años de vigencia tiene esta teoría, lo que justifica su fuerza explicativa. Mucho tiempo, sin duda, en el que los profesionales de la educación nos hemos familiarizado sobre todo con la idea de significatividad del aprendizaje y hemos intentado lograrlo en nuestro alumnado, no siempre con el éxito deseado. Supuestamente al amparo de la Teoría del Aprendizaje Significativo se han planificado muchas programaciones escolares y programas curriculares y en el fondo no sabemos muy bien cuáles son sus aspectos más destacados, aquéllos que hubiesen podido ayudarnos a comprender los entresijos que definen al aprendizaje significativo y que lo hacen posible. Por eso se hace necesario adentrarnos en la teoría en sí y profundizar en la misma, de manera que la aprendamos significativamente para, con ello, lograr que los aprendizajes que pretendemos de nuestros estudiantes (relativos a los contenidos científica y contextualmente validados) sean realmente significativos. Ése es el objeto de esta exposición. Para ello, se dedica una primera parte a la caracterización de la teoría como tal. En un segundo apartado se tratan los conceptos definitorios de la misma, fundamentalmente, el constructo "aprendizaje significativo", que se analiza primero desde una perspectiva ausubeliana y, después con las aportaciones que lo han enriquecido, aumentando así su comprensión y su aplicabilidad. Con objeto de aclarar y especificar su potencialidad en el aula, se termina este apartado con una revisión de algunos usos poco acertados de dicho constructo. Se analizan también algunas consecuencias derivadas de esta teoría y, por último, se lleva a cabo una revisión del aprendizaje significativo desde la perspectiva de la Teoría de los Modelos Mentales de Johnson-Laird y la Teoría de los Campos Conceptuales de Vergnaud.

¿Qué es la Teoría del Aprendizaje Significativo?

Podemos considerar a la teoría que nos ocupa como una teoría psicológica del aprendizaje en el aula. Ausubel (1973, 1976, 2002) ha construido un marco teórico que pretende dar cuenta de los mecanismos por los que se lleva a cabo la adquisición y la retención de los grandes cuerpos de significado que se manejan en la escuela.

Es una teoría psicológica porque se ocupa de los procesos mismos que el individuo pone en juego para aprender. Pero desde esa perspectiva no trata temas relativos a la psicología misma ni desde un punto de vista general, ni desde la óptica del desarrollo, sino que pone el énfasis en lo que ocurre en el aula cuando los estudiantes aprenden; en la naturaleza de ese aprendizaje; en las condiciones que se requieren para que éste se produzca; en sus resultados y, consecuentemente, en su evaluación (Ausubel, 1976). Es una teoría de aprendizaje porque ésa es su finalidad. La Teoría del Aprendizaje Significativo aborda todos y cada uno de los elementos, factores, condiciones y tipos que garantizan la adquisición, la asimilación y la retención del contenido que la escuela ofrece al alumnado, de modo que adquiera significado para el mismo.

Pozo (1989) considera la Teoría del Aprendizaje Significativo como una teoría cognitiva de reestructuración; para él, se trata de una teoría psicológica que se construye desde un enfoque organicista del individuo y que se centra en el aprendizaje generado en un contexto escolar. Se trata de una teoría constructivista, ya que es el propio individuo-organismo el que genera y construye su aprendizaje.

El origen de la Teoría del Aprendizaje Significativo está en el interés que tiene Ausubel por conocer y explicar las condiciones y propiedades del aprendizaje, que se pueden relacionar con formas efectivas y eficaces de provocar de manera deliberada cambios cognitivos estables, susceptibles de dotar de significado individual y social (Ausubel, 1976). Dado que lo que quiere conseguir es que los aprendizajes que se producen en la escuela sean significativos, 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. Así mismo, y con objeto de lograr esa significatividad, debe prestar atención a todos y cada uno de los elementos y factores que le afectan, que pueden ser manipulados para tal fin.

Desde este enfoque, la investigación es, pues, compleja. Se trata de una indagación que se corresponde con la psicología educativa como ciencia aplicada. El objeto de la misma es destacar "*los principios que gobiernan la naturaleza y las condiciones del aprendizaje escolar*" (op. cit., pág. 31), lo que requiere procedimientos de investigación y protocolos que atiendan tanto a los tipos de aprendizaje que se producen en el aula, como a las características y rasgos psicológicos que el estudiante pone en juego cuando aprende. De igual modo, es relevante para la investigación el estudio mismo de la materia objeto de enseñanza, así como la organización de su contenido, ya que resulta una variable del proceso de aprendizaje.

¿Cuáles son los conceptos-clave de la teoría?

Lo que define a la teoría ausubeliana es el "aprendizaje significativo", una etiqueta que está muy presente en el diálogo de docentes, diseñadores del currículum e investigadores en educación y que, sin embargo, son muchos también los que desconocen su origen y su justificación. Precisamente por eso, conviene que se haga una revisión sobre su significado y sobre la evolución que ha seguido. El objeto de este apartado es analizar el sentido y la potencialidad del constructo como tal. Para ello se abordará una primera parte relativa al aprendizaje significativo en sí, analizada bajo dos puntos de vista: la posición de Ausubel, por un lado, y, por otro, las aportaciones y reformulaciones realizadas a lo largo de este tiempo. Esto permitirá que pasemos revista, en la segunda parte, a algunos malos entendidos y confusiones con respecto al sentido que se le atribuye a aprendizaje significativo o a su aplicación. De este modo, se obtendrá una visión de conjunto que delimite algunas conclusiones significativas al respecto y posibilite una mejor comprensión y aplicación del constructo en el aula.

Aprendizaje significativo: una revisión de su significad.

1.- Perspectiva ausubeliana.

El aprendizaje significativo es el proceso según el cual se relaciona un nuevo conocimiento o información con la estructura cognitiva del que aprende de forma no arbitraria y sustantiva o no literal. Esa interacción con la estructura cognitiva no se produce considerándola como un todo, sino con aspectos relevantes presentes en la misma, que reciben el nombre de subsumidores o ideas de anclaje (Ausubel, 1976, 2002; Moreira, 1997). La presencia de ideas, conceptos o proposiciones inclusivas, claras y disponibles en la mente del aprendiz es lo que dota de significado a ese nuevo contenido en interacción con el mismo (Moreira, 2000 a). Pero no se trata de una simple unión, sino que en este proceso los nuevos contenidos adquieren significado para el sujeto produciéndose una transformación de los subsumidores de su estructura cognitiva, que resultan así progresivamente más diferenciados, elaborados y estables (ibid.).

Pero aprendizaje significativo no es sólo este proceso, sino que también es su producto. La atribución de significados que se hace con la nueva información es el resultado emergente de la interacción entre los subsumidores claros, estables y relevantes presentes en la estructura cognitiva y esa nueva información o contenido; como consecuencia del mismo, esos subsumidores se ven enriquecidos y modificados, dando lugar a nuevos subsumidores o ideas-ancla más potentes y explicativas que servirán de base para futuros aprendizajes.

Para que se produzca aprendizaje significativo han de darse dos condiciones fundamentales:

- Actitud potencialmente significativa de aprendizaje por parte del aprendiz, o sea, predisposición para aprender de manera significativa.
- Presentación de un material potencialmente significativo. Esto requiere:
    - Por una parte, que el material tenga significado lógico, esto es, que sea potencialmente relacionable con la estructura cognitiva del que aprende de manera no arbitraria y sustantiva;

- Y, por otra, que existan ideas de anclaje o subsumidores adecuados en el sujeto que permitan la interacción con el material nuevo que se presenta.

Atendiendo al objeto aprendido, el aprendizaje significativo puede ser *representacional*, *de conceptos* y *proposicional*. Si se utiliza como criterio la organización jerárquica de la estructura cognitiva, el aprendizaje significativo puede ser *subordinado*, *superordenado* o *combinatorio*.

Para Ausubel lo que se aprende son palabras u otros símbolos, conceptos y proposiciones. Dado que el aprendizaje representacional conduce de modo natural al aprendizaje de conceptos y que éste está en la base del aprendizaje proposicional, los conceptos[1] constituyen un eje central y definitorio en el aprendizaje significativo. A través de la asimilación se produce básicamente el aprendizaje en la edad escolar y adulta. Se generan así combinaciones diversas entre los atributos característicos de los conceptos que constituyen las ideas de anclaje, para dar nuevos significados a nuevos conceptos y proposiciones, lo que enriquece la estructura cognitiva. Para que este proceso sea posible, hemos de admitir que contamos con un importantísimo vehículo que es el lenguaje: el aprendizaje significativo se logra por intermedio de la verbalización y del lenguaje y requiere, por tanto, comunicación entre distintos individuos y con uno mismo.

En la programación del contenido de una disciplina encaminada a la consecución de aprendizajes significativos en el alumnado han de tenerse en cuenta cuatro principios (Ausubel, 1976): *diferenciación progresiva*, *reconciliación integradora*, *organización secuencial* y *consolidación*.

Este primer apartado se ha destinado a una breve revisión del constructo de aprendizaje significativo en la perspectiva ausubeliana. Se han abordado su definición, las condiciones en las que se produce, los principios y procesos que lo caracterizan, los tipos, la aparición de los conceptos, su facilitación y el papel que tiene el lenguaje en todo ello.

2.- Aportaciones al constructo.

El tiempo trascurrido desde que surgió el constructo aprendizaje significativo ha sido mucho. Llama la atención su perdurabilidad, sobre todo si tenemos en cuenta que nos movemos en el ámbito de un conjunto de disciplinas científicas consideradas jóvenes, que evolucionan y cambian a gran velocidad. Probablemente la clave de "su éxito" está en que aparentemente es un constructo simple a la mano de todos los docentes y diseñadores del currículum, pero de una extraordinaria complejidad y, sobre todo, insuficientemente comprendido (Novak, 1998), lo que dificulta su aplicación a contextos concretos (tanto curriculares como docentes, en el aula).

Con el ánimo de profundizar en su significado son varios los investigadores que han ido enriqueciendo el constructo, aportando matices y modos de utilizarlo. Lo que sigue no es una revisión exhaustiva a este respecto, sino tan sólo algunas aportaciones que han resultado significativas como reflexiones necesarias que mejoran su entendimiento y amplían sus horizontes, lo que le garantiza una vida mucho más larga.

A) Aprendizaje significativo: pensamiento, sentimiento y acción.

Aprendizaje significativo es también el constructo central de la Teoría de Educación de Novak (1988, 1998). Ya Ausubel (1976, 2002) delimita el importante papel que tiene la predisposición por parte del aprendiz en el proceso de construcción de significados, pero es Novak quien le da carácter humanista al término, al considerar la influencia de la experiencia emocional en el proceso de aprendizaje. *"Cualquier evento educativo es, de acuerdo con Novak, una* ***acción*** *para intercambiar* ***significados*** *(pensar) y* ***sentimientos*** *entre el aprendiz y el profesor*" (Moreira, 2000 a, pág. 39/40). La negociación y el intercambio de significados entre ambos protagonistas del evento educativo se constituye así en un eje primordial para la consecución de aprendizajes significativos. Otra aportación muy importante de Novak son los mapas conceptuales.

B) Aprendizaje significativo: significados y responsabilidades compartidos.

Según Ausubel (2002), aprender significativamente o no forma parte del ámbito de decisión del individuo, una vez que se cuenta con los subsumidores relevantes y con un material que reúne los requisitos pertinentes de significatividad lógica. El papel del sujeto ya es destacado, tanto por Ausubel como por Novak, como acabamos de ver. La idea de aprendizaje significativo como proceso en el que se comparten significados y se delimitan responsabilidades está, no obstante, desarrollada en profundidad en la Teoría de Educación de Gowin (1981).

[1] "Ausubel (1978, p.86) define conceptos como *"objetos, eventos, situaciones o propiedades que poseen atributos criteriales comunes y se designan, en una cultura dada, por algún signo (...) aceptado"* (Moreira, 2000 a, pág. 21).

Como elementos de un evento educativo, el profesor, el aprendiz y los materiales educativos del currículum constituyen un eje básico en el que, partiendo de éstos últimos, las personas que lo definen intentan deliberadamente llegar a acuerdos sobre los significados atribuidos. *"La enseñanza se consuma cuando el significado del material que el alumno capta es el significado que el profesor pretende que ese material tenga para el alumno."* (Gowin, 1981, pág. 81). Gowin también aporta un instrumento de metaaprendizaje: la V heurística o epistemológica.

C) Aprendizaje significativo: un constructo subyacente.

Aprendizaje significativo puede considerarse una idea suprateórica que resulta compatible con distintas teorías constructivistas, tanto psicológicas como de aprendizaje, subyaciendo incluso a las mismas (Moreira, 1997). Es posible, por ejemplo, relacionar la asimilación, la acomodación y la equilibración piagetianas con el aprendizaje significativo; se pueden también correlacionar los constructos personales de Kelly con los subsumidores; cabe interpretar la internalización vygotskyana con la transformación del significado lógico de los materiales en significado psicológico, lo mismo que es destacable el papel de la mediación social en la construcción del conocimiento; podemos también concluir que el aprendizaje será tanto más significativo cuanto mayor sea la capacidad de los sujetos de generar modelos mentales cada vez más explicativos y predictivos.

D) Aprendizaje significativo: un proceso crítico.

El aprendizaje significativo depende de las motivaciones, intereses y predisposición del aprendiz. El estudiante no puede engañarse a sí mismo, dando por sentado que ha atribuido los significados contextualmente aceptados, cuando sólo se ha quedado con algunas generalizaciones vagas sin significado psicológico (Novak, 1998) y sin posibilidades de aplicación. Es crucial también que el que aprende sea crítico con su proceso cognitivo, de manera que manifieste su disposición a analizar desde distintas perspectivas los materiales que se le presentan, a enfrentarse a ellos desde diferentes puntos de vista, a trabajar activamente por atribuir los significados y no simplemente a manejar el lenguaje con apariencia de conocimiento (Ausubel, 2002). Nuevamente es Moreira (2000 b) quien trata de modo explícito el carácter crítico del aprendizaje significativo; para ello integra los presupuestos ausubelianos con la enseñanza subversiva que plantean Postman y Weingartner (1969, citados por Moreira, 2000 b). Al identificar semejanzas y diferencias y al reorganizar su conocimiento, el aprendiz tiene un papel activo en sus procesos de aprendizaje. Como Gowin plantea, ésta es su responsabilidad, y como Ausubel señala, depende de la predisposición o actitud significativa de aprendizaje. Esta actitud debe afectar también a la propia concepción sobre el conocimiento y su utilidad. Debemos cuestionarnos qué es lo que queremos aprender, por qué y para qué aprenderlo y eso guarda relación con nuestros intereses, nuestras inquietudes y, sobre todo, las preguntas que nos planteemos.

Aprendizaje significativo: un resumen.

Hagamos una síntesis. Aprendizaje significativo es el proceso que se genera en la mente humana cuando subsume nuevas informaciones de manera no arbitraria y sustantiva y que requiere como condiciones: predisposición para aprender y material potencialmente significativo que, a su vez, implica significatividad lógica de dicho material y la presencia de ideas de anclaje en la estructura cognitiva del que aprende. Es subyacente a la integración constructiva de pensar, hacer y sentir, lo que constituye el eje fundamental del engrandecimiento humano. Es una interacción triádica entre profesor, aprendiz y materiales educativos del currículum en la que se delimitan las responsabilidades correspondientes a cada uno de los protagonistas del evento educativo. Es una idea subyacente a diferentes teorías y planteamientos psicológicos y pedagógicos que ha resultado ser más integradora y eficaz en su aplicación a contextos naturales de aula, favoreciendo pautas concretas que lo facilitan. Es, también, la forma de encarar la velocidad vertiginosa con la que se desarrolla la sociedad de la información, posibilitando elementos y referentes claros que permitan el cuestionamiento y la toma de decisiones necesarios para hacerle frente a la misma de una manera crítica Pero son muchos los aspectos y matices que merecen una reflexión que pueda ayudarnos a aprender significativa y críticamente de nuestros errores en su uso o aplicación. De esto es de lo que se ocupa el apartado siguiente (Rodríguez, 2003 a).

Aprendizaje significativo: algunas incorrecciones contextuales en su aplicación.

Una vez que se ha expuesto el sentido atribuido al constructo aprendizaje significativo, así como su evolución, hemos de hacer válida la opinión de Moreira (1997) de que se ha trivializado su utilización, ya que todos “hacemos” aprendizaje significativo con nuestros alumnos y en muchos casos se desconoce su significado, su evolución y la fundamentación teórica que lo avala. Lo que sigue pretende servir de revisión de algunos de esos tópicos o aspectos mal comprendidos con respecto al constructo que, en ningún caso, constituirá una relación exhaustiva de los mismos. Su finalidad no es otra que la de ayudar a mejorar nuestro conocimiento sobre el tema en el contexto de la teoría expuesta y de ninguna manera pretende ser descalificante.

No es posible desarrollar aprendizajes significativos si no se cuenta con una actitud significativa de aprendizaje. **No** se genera tampoco aprendizaje significativo si no están presentes las ideas de anclaje pertinentes en la estructura cognitiva del aprendiz. Aprendizaje significativo **no** es lo mismo que aprendizaje (que puede ser mecánico) de material lógicamente significativo; no cabe confundir el proceso con el material con el que se realiza. El aprendizaje significativo **no** se produce de manera súbita, sino que se trata de un proceso demorado que requiere su tiempo; el aprendizaje significativo no se produce instantáneamente sino que requiere intercambio de significados y ese proceso puede ser largo. Aprendizaje significativo **no** es necesariamente aprendizaje correcto; siempre que haya una conexión no arbitraria y sustantiva entre la nueva información y los subsumidores relevantes se produce un aprendizaje significativo, pero éste puede ser erróneo desde el punto de vista de una comunidad de usuarios. Aprendizaje significativo **no** es lenguaje, no es simplemente un modo específico de comunicación aprendiz/profesor. **No** se puede desarrollar aprendizaje significativo en el alumnado con una organización del contenido escolar lineal y simplista; significado lógico es una cosa y significado psicológico es otra. Aprendizaje significativo **no** es el uso de mapas conceptuales y/o diagramas V; no podemos confundir el proceso en sí con herramientas que pueden facilitarlo o potenciarlo. **No** hay aprendizaje significativo sin la interacción personal (Rodríguez, 2003 a).

¿Qué consecuencias se derivan de su consideración?

Una consecuencia natural de esta teoría es su consideración del carácter progresivo que tiene el aprendizaje significativo a través del tiempo. Se caracteriza por su aspecto evolutivo a lo largo del desarrollo del individuo.

La Teoría del Aprendizaje Significativo tiene importantes consecuencias pedagógicas. Lo que pretende es la manipulación de la estructura cognitiva, bien para conocerla o bien para introducir en ella elementos que le permitan dotar de significatividad al contenido que se le presente posteriormente. Se requiere un proceso de organización sustancial, por un lado, tendente a identificar los conceptos esenciales que articulan una disciplina, y programática, por otro, cuyo propósito es trabajarlos de modo adecuado para que resulten significativamente aprendidos. Los principios programáticos de diferenciación progresiva, reconciliación integradora, organización secuencial y consolidación se constituyen en una ayuda para planificar una enseñanza acorde con esta teoría.

Para Ausubel (ibid.), "la exposición verbal es en realidad la manera más eficiente de enseñar la materia de estudio y produce conocimientos más sólidos y menos triviales que cuando los alumnos son sus propios pedagogos". Esta consideración guarda relación con la polémica relativa a la enseñanza receptiva vs por descubrimiento y resolución de problemas. Ausubel entiende que es desacertado plantear que el aprendizaje sólo se produce cuando se plantean estrategias de este último tipo. La crítica a la enseñanza verbal expositiva es inconsistente. Este rechazo no se corresponde con la visión ausubeliana del desarrollo cognitivo. El problema fundamental se centra en el desconocimiento de cómo se producen los procesos de aprendizaje (articulados en torno a una estructura jerárquica de la mente) y en la aplicación de programas educativos y planes de enseñanza inadecuados, que no respetan los aspectos sustanciales y programáticos del contenido de las asignaturas objeto de estudio por parte de los estudiantes, tendentes a su adquisición y retención significativas (Ausubel, 1973).

Como se desprende de lo anterior, la Teoría del Aprendizaje Significativo no está libre de críticas. Se trata de una construcción teórica que tiene también elementos y aspectos que han sido cuestionados, como es el papel de la transmisión verbal en la producción significativa del conocimiento, ya tratado. Otras discrepancias son más profundas y afectan a su propia concepción.

Para Pozo (1989, pág. 220-221) "la idea de que la mayor parte de los conceptos se adquiere por diferenciación de otros más generales es, cuando menos, discutible, tanto si nos referimos a los aprendizajes naturales o espontáneos como a los artificiales o científicos"; la Teoría del Aprendizaje Significativo considera de manera insuficiente los procesos inductivos y su papel en la generación del conocimiento. Pero Pozo (ibid.) sostiene una diferencia aún más profunda. Para él, Ausubel desarrolla insuficientemente la función de la toma de conciencia en la reestructuración del conocimiento. Este autor entiende que esta cuestión se pone claramente de manifiesto sobre todo en el planteamiento didáctico de su teoría, en el que se muestra una falta de atención a la naturaleza y a la persistencia de los conceptos previos del alumno cuando se aplican estrategias expositivas.

Recientemente, Galagovsky (2004) cuestiona algunas significaciones atribuidas a esta teoría y lleva a cabo una revisión crítica de las mismas. Algunas de estas confusiones se corresponden con la atribución errónea del adjetivo "significativo" con motivación. Éste no es el sentido que le ha atribuido Ausubel a este adjetivo; el aprendizaje significativo requiere una actitud significativa de aprendizaje, pero es mucho más que motivación. También cuestiona la correlación aprendizaje significativo ↔ aprendizaje correcto o la equiparación aprendizaje significativo/contenido significativo o lo que desde la perspectiva ausubeliana sería contenido o material potencialmente significativo o, incluso, material lógicamente significativo. Ausubel (1973, 1976, 2002) es explícito a este respecto, por lo que esa interpretación no se corresponde con la teoría que él ha postulado. Galagovsky (ibid.) propone el modelo de aprendizaje cognitivo consciente sustentable, estableciendo diferenciaciones entre subsumidor y concepto-sostén, y destaca el papel de la conciencia porque considera que no está valorizada en la Teoría del Aprendizaje Significativo. Los argumentos utilizados como crítica no parecen ser lo suficientemente consistentes como para descartar este referente y proponer otro nuevo que, en el fondo, no supone novedad o manifiesta ciertos olvidos con respecto a la teoría que nos ocupa.

No cabe duda, como Pozo (1989) apunta, de que estamos ante una teoría psicológica cognitiva del aprendizaje que adquiere sentido y carta de naturaleza en su aplicación a la enseñanza. Ello requiere un conocimiento suficiente de la misma que nos permita ciertas garantías de éxito en su aplicación, un éxito que en este caso será la producción de aprendizajes significativos por parte del alumnado. Probablemente, la ausencia de resultados positivos o su insuficiencia tengan relación con el desconocimiento de sus premisas fundamentales y/o con equívocos en su puesta en práctica. Son innegables sus consecuencias pedagógicas y, quizás, la más crucial sea la necesidad de tener un profundo conocimiento de la teoría como tal y de llevar a cabo un aprendizaje significativo de la misma que nos permita aplicarla en el aula correctamente.

La Teoría del Aprendizaje Significativo desde la perspectiva de la Psicología Cognitiva.

El avance en la psicología cognitiva ha sido espectacular y son muchas las teorías psicológicas y de aprendizaje que se nos ofrecen para comprender cómo se produce y cómo se facilita la cognición. La Teoría del Aprendizaje Significativo es una de ellas y ya tiene cuarenta años de historia. En tiempos recientes han surgido otras teorías psicológicas que tratan los procesos implicados en la cognición, cuyo objetivo es facilitar una mejor comprensión de los mismos. Es imposible en este espacio abordarlas todas; se ha optado por seleccionar dos de ellas, la Teoría de los Modelos Mentales (Johnson-Laird) y la Teoría de los Campos Conceptuales (Vergnaud) porque conjuntamente ofrecen un marco de referencia que apoya consistentemente los presupuestos, principios, condiciones y características expresados por Ausubel (1973, 1976, 2002) en la Teoría del Aprendizaje Significativo. Para ello se explican a continuación brevemente ambas teorías; se analiza una visión conjunta de las mismas para, posteriormente, correlacionar la propuesta ausubeliana con la posición de Vergnaud. Con este bagaje se discute, finalmente, el aprendizaje significativo desde este enfoque cognitivo más actual.

La Teoría de los Modelos Mentales de Johnson-Laird.

Modelos mentales como forma de analizar las representaciones se ha convertido en la referencia actual. La investigación educativa ha mostrado la necesidad de abordar el conocimiento desde un enfoque psicológico. Surgen, así, los modelos mentales como mecanismo para comprender el modo según el cual se interpreta el mundo; una de esas posibilidades la ofrece la Teoría de los Modelos Mentales de Johnson-Laird (1983, 1996).

Se trata de una teoría de la mente adecuada explicativamente porque atiende tanto a la forma de la representación (proposiciones, modelos mentales e imágenes) como a los procedimientos que permiten construirla y manipularla: mente computacional, procedimientos efectivos, revisión recursiva y modelos mentales (Johnson-Laird, 1983, 1996) y todo ello construido sobre la base de un lenguaje mental propio, que da cuenta tanto de la forma de esa representación como de los procesos que con ella se producen. Esa representación trabaja sobre un contenido al que de este modo se le asigna significado (Rodríguez, Marrero y Moreira, 2001; Rodríguez, 2003 b). Johnson-Laird plantea que ante la imposibilidad de aprehender el mundo directamente, la mente construye representaciones internas que actúan como intermediarias entre el individuo y su mundo, posibilitando su comprensión y su actuación en él. Según él, el razonamiento se lleva a cabo con modelos mentales, la mente humana opera con modelos mentales como piezas cognitivas que se combinan de diversas maneras y que "re-presentan" los objetos y/o las situaciones, captando sus elementos y atributos más característicos. Pero esos modelos mentales se construyen y en ellos se pueden utilizar otras representaciones: proposiciones e imágenes. Con el constructo "modelo mental" Johnson-Laird postula una representación integradora. El autor nos está diciendo que la persona usa representaciones internas que pueden ser proposiciones, modelos mentales e imágenes. "*Las representaciones proposicionales son cadenas de símbolos que corresponden al lenguaje natural. Los modelos mentales son análogos estructurales del mundo y las imágenes son modelos vistos desde un determinado punto de vista".* (Johnson-Laird, 1983, pág. 165). Los modelos mentales y las imágenes constituyen lenguajes de alto nivel, ya que son analógicas, mientras que las proposiciones no, por ser representaciones discretas, abstractas, rígidas, adquiriendo sus condiciones de verdad a la luz de un modelo mental; las proposiciones como tales son representaciones no analógicas.

La Teoría de los Campos Conceptuales de Vergnaud.

La construcción teórica de Vergnaud es una teoría psicológica que atiende a la complejidad cognitiva; se ocupa de los mecanismos que conducen a la conceptualización de lo real. El objeto que persigue Vergnaud (1996) es entender cuáles son los problemas de desarrollo específicos de un campo de conocimiento. Ese conocimiento lo aprehende el sujeto formando parte de sus estructuras cognitivas por un proceso de integración adaptativa con las situaciones que vive, proceso que se desarrolla a lo largo del tiempo. Se trata de una teoría psicológica cognitiva que se ocupa del estudio del desarrollo y del aprendizaje de conceptos y competencias complejas, lo que permite explicar el modo en el que se genera el conocimiento, entendiendo como tal tanto los saberes que se expresan como los procedimientos, o sea, el saber decir y el saber hacer (Vergnaud, 1990, 1996).

El constructo que da nombre a la teoría es "campo conceptual", idea a la que se llega porque se entiende que es absurdo abordar por separado el estudio de conceptos que están interconectados. Se considera que esos conceptos, que no tienen sentido aisladamente, se construyen y operan en el conocimiento humano en función de las situaciones a las que el sujeto se enfrenta y en ese proceso entran en juego procedimientos, concepciones y representaciones simbólicas, con el objeto de dominar esas situaciones (Vergnaud, 1983). Un campo conceptual es un conjunto de situaciones en las que el manejo, el análisis y el tratamiento que realiza la persona requieren una variedad de conceptos, procedimientos y representaciones interconectadas en estrecha conexión. El campo conceptual se relaciona directamente con las situaciones que lo reclaman y eso guarda relación con las tareas. Vergnaud (1996) pone el acento en el sujeto en situación, su forma de organizar la conducta y su modo de conceptuar ante esa situación y para ello utiliza el concepto de esquema de Piaget. Considera que éstos constituyen el centro de la adaptación de las estructuras cognitivas, jugando un papel esencial en la asimilación y en la acomodación, ya que un esquema se apoya en una conceptualización implícita.

La Teoría de los Campos Conceptuales tiene múltiples posibilidades en distintas áreas del conocimiento. Se trata de una teoría de la que se derivan diversas consideraciones de interés, tanto de carácter psicológico como pedagógico, destacándose, fundamentalmente, su concepción de esquema como representación mental estable que opera en la memoria a largo plazo. Es una teoría cognitiva que permite comprender y explicar aspectos cruciales del proceso de la cognición.

La construcción del conocimiento en la perspectiva conjunta de la Teoría de los Modelos Mentales y la Teoría de los Campos Conceptuales.

Desarrollar conocimiento no es más que una paulatina construcción de representaciones mentales, que dan cuenta de la realidad; ésta se termina conceptuando a través de esquemas (Rodríguez y Moreira, 2002 b). En la medida en que un esquema de asimilación es la organización invariante de la conducta y que incluye invariantes operatorios, es una estructura mental que goza de estabilidad. Pero ¿cómo se construye? ¿Cuál es su fuente para determinar, así, el conocimiento del que dispone la persona que lo posee? ¿Cómo llega un esquema a tener invariantes que determinen una organización de la conducta similar ante situaciones también similares? Una vez construido un esquema, el sujeto lo usa, asimilando así situaciones de una determinada clase. Pero ante algo nuevo, necesita algún mecanismo útil que le permita aprehenderlo, captar esa nueva situación y hacerle frente; ese algo es una representación que lo dota de poder explicativo y predictivo y eso es un modelo mental. Una vez que esa nueva situación deja de serlo al presentársele repetidamente, el individuo adquiere dominio sobre esta clase, dando lugar a una organización invariante de su conducta y eso es un esquema (Moreira, 2002; Greca y Moreira, 2002; Rodríguez y Moreira, 2002 a). Así, se establece un puente entre aquello que constituye la representación primera en la memoria episódica (modelos mentales) y aquello que permanece en la memoria de largo plazo (esquema). Pueden explicarse, pues, los procesos de aprendizaje, tanto los "académicamente" establecidos como aquéllos que resultan erróneos, ya que esos esquemas insuficientemente explicativos condicionan los modelos mentales de los que se nutren y viceversa. Podrían entenderse de este modo las respuestas equivocadas que dan los estudiantes reiterativamente sobre algunos conceptos científicos, puesto que se deben a invariantes que la docencia no ha sido capaz de modificar. El aprendizaje del conocimiento científico supone, consecuentemente, la modificación de los esquemas y, por ende y para ello, la reestructuración y el enriquecimiento de los modelos mentales que los jóvenes generan como fuente de los mismos.

Este marco explicativo conjunto puede ofrecer explicaciones que nos permitan alcanzarlo o, al menos, mejorarlo en el alumnado, de tal modo que sus esquemas de asimilación respondan más fielmente al conocimiento científico validado hasta el momento que la escuela pretende enseñar.

__Teoría del Aprendizaje Significativo vs Teoría de los Campos Conceptuales.__

Según Caballero (2003), la Teoría del Aprendizaje Significativo y la Teoría de los Campos Conceptuales son coincidentes al considerar que la significatividad del aprendizaje es un proceso progresivo que requiere tiempo. En ambas se hace necesario llevar a cabo el análisis conceptual del contenido objeto de estudio. Para la autora (ibid.), el referente de los campos conceptuales propuesto por Vergnaud (1983, 1990) permite comprender, explicar e investigar procesos de aprendizaje significativo. Se trata de teorías psicológicas (una del aprendizaje y otra de la conceptualización de lo real) cuyos objetos de análisis, conceptos-clave, procedimientos de validación y ampliación son distintos, pero que tienen muchos aspectos en común. La Teoría de los Campos Conceptuales aporta un nuevo modo de "ver" el aprendizaje significativo, sobre todo en lo que se refiere a los conceptos. Efectivamente, complementa su concepción, revalorizándolo en el sentido de que lo que resulta significativo y, por tanto, perdurable, es el esquema de asimilación que determina la conducta. Los principios y presupuestos vergnaudnianos, como fundamentos psicológicos de la cognición que son, ayudan a entender cómo es y cómo se produce el aprendizaje significativo, ampliando, por tanto, las posibilidades ausubelianas, tanto para la investigación en educación como para la docencia.

__Aprendizaje Significativo: una visión cognitiva conjunta.__

¿Qué es aprendizaje significativo desde esta perspectiva global de la Teoría del Aprendizaje Significativo, la Teoría de los Modelos Mentales y la Teoría de los Campos Conceptuales? Un aprendizaje significativo no se puede borrar por su condición de diferenciado, estable y perdurable, ya que está anclado en los subsumidores que lo han permitido y le han dado origen, aunque sea científica y contextualmente no aceptado por la comunidad de usuarios. El proceso de asimilación que conduce al aprendizaje significativo es evolutivo; se trata de un fenómeno progresivo y no de sustitución del tipo "todo o nada"; el propio subsumidor se ve modificado. La adquisición y el aprendizaje de conceptos se caracterizan por su progresividad (Caballero, 2003).

Para Moreira (2002), Greca y Moreira (2002), Rodríguez y Moreira (2002 a) y Moreira y Greca (2003) la mente opera con representaciones determinadas por los invariantes operatorios de los esquemas (supuestos psicológicos). En esas representaciones es en donde se plasma el conocimiento del individuo. Los modelos mentales son representaciones que se ejecutan en la memoria episódica; los esquemas de asimilación se construyen en la memoria a largo plazo y por eso tienen carácter de estabilidad. Tanto los modelos mentales como los esquemas se pueden definir por los invariantes operatorios que los caracterizan.

Al construir un esquema, la persona lo usa asimilando de ese modo una determinada clase de situaciones. Dado que es la organización invariante de la conducta ante las mismas circunstancias y en contextos similares, ese esquema permite su dominio. Pero al enfrentarse a una situación nueva -un mundo nuevo- para la que el esquema no es suficientemente eficaz ni válido, éste ya no funciona, lo que reclama por parte del sujeto algún mecanismo que le permita asimilarla. Para ello, podría pensarse que se construye un modelo mental que actúa de intermediario (modelo mental que resulta de la aplicación de elementos de varios esquemas) y que permite hacerle frente a esa nueva realidad. El dominio progresivo de la misma podría llevar también a una paulatina estabilización de esa primera representación, lo que nos conduce a su transformación en esquema de asimilación (Moreira, 2002). Hemos de tener en cuenta que nuevos invariantes son los que condicionan nuevos conceptos y teoremas-en-acción y, por lo tanto, nuevos esquemas. Debemos considerar también que tanto los modelos mentales como los esquemas pueden contener esos invariantes o, para ser más precisos, que los invariantes operatorios de los esquemas determinan los modelos metales que se ejecuten, y que, consecuentemente, una vez que los modelos mentales vayan dando un mayor dominio por revisión recursiva, pueden ir constituyéndose en esquemas de asimilación (Greca y Moreira, 2002).

¿Cómo se produce la asimilación y la retención del contenido en este contexto representacional? ¿Cómo se puede explicar la construcción de aprendizaje significativo? La nueva información potencialmente significativa, **a**, (que se corresponderá con una nueva situación), interactúa con una idea de anclaje o subsumidor, **A**, generando el producto de interacción **a´A´,** ya que ambos se ven modificados en esa interacción porque se produce interpretación del nuevo contenido por parte del sujeto, en función del subsumidor relevante que utilice. Esa interpretación que se produce en la hora (en la memoria episódica) puede entenderse como un modelo mental. La idea de anclaje o subsumidor puede considerarse como un esquema de asimilación, en tanto que idea relevante, clara y estable presente en la estructura cognitiva (en la memoria a largo plazo). Si se expone a la persona a situaciones similares, se va produciendo dominio de las mismas, lo que conduce a que se active el mismo esquema, ya que está presente en su estructura cognitiva. No se requiere la construcción de un modelo mental, puesto que se dispone de una representación cognitiva más estable, que es el esquema de asimilación. Ante una situación novedosa que no puede ser tratada cognitivamente con este esquema, porque no resulta suficientemente explicativo y predictivo, esto es, no permite una automatización u organización invariante de la conducta, el individuo genera nuevamente un modelo mental que le permite aprehender su mundo en la hora, en el momento en el que le surge lo inesperado. De este modo, se produce una interacción dialéctica entre modelos mentales y esquemas que justifica la asimilación y la retención de nuevo contenido y, por lo tanto, el aprendizaje significativo, dado que **A´** (lo que queda en la estructura cognitiva) es un esquema de asimilación modificado, más rico, más explicativo, originado con el concurso del modelo mental y del esquema.

La Teoría del Aprendizaje Significativo sigue siendo un potente referente explicativo que se ve fuertemente reforzado por la Teoría de los Modelos Mentales y la Teoría de los Campos Conceptuales, como apoyos representacionales que dan cuenta de cómo se produce la asimilación y la retención del conocimiento. Con esta explicación psicológica conjunta se abren múltiples posibilidades para la investigación en educación y para la docencia, un marco que posibilita que efectivamente se alcance el aprendizaje significativo en el aula.

Conclusiones.

La Teoría del Aprendizaje Significativo es un referente teórico de plena vigencia, como muestra el simple hecho de que ha sido "lugar común" de docentes, investigadores y diseñadores del currículum durante más de cuarenta años. Pero es también una gran desconocida, en el sentido de que muchos de sus elementos no han sido captados, comprendidos o "aprendidos significativamente" por parte de los que nos dedicamos a la enseñanza.

Aprendizaje significativo sigue siendo un constructo de una gran potencia explicativa, tanto en términos psicológicos como pedagógicos. Ese gran poder de convicción es lo que justifica su vigor. Pero haciendo gala del sentido crítico que le atribuye Moreira (2000 b), hemos de cuestionarnos el uso que se está haciendo del mismo. El aprendizaje significativo no es posible sin la predisposición para aprender o una actitud de aprendizaje significativa. No puede desarrollarse si no se dispone de los subsumidores adecuados en la estructura cognitiva. No es factible si el material no es lógicamente significativo, lo que no podemos confundir con el proceso en sí mismo. No es súbito ni surge instantáneamente. No es necesariamente aprendizaje correcto. No se produce sin la intervención del lenguaje. No se facilita con cualquier organización o tratamiento del contenido curricular. No es el uso de instrumentos facilitadores (como, por ejemplo, mapas conceptuales y V epistemológicas). No es un proceso independiente que se produzca al margen de la interacción personal.

La Teoría del Aprendizaje Significativo tiene importantes implicaciones psicológicas y pedagógicas. Considera que el aprendizaje se construye de manera evolutiva. Porque se ocupa de lo que ocurre en el aula, postula los principios programáticos para organizar la docencia y, en este sentido, adquiere un valor especial la necesidad de realizar un análisis conceptual del contenido que huya de planteamientos simplistas.

Es una teoría viva que no sólo se ha limitado a resistir durante tanto tiempo, sino que ha evolucionado a lo largo de su historia, a través de las distintas contribuciones que ha recibido. La aplicación de sus principios a la investigación en educación y a la enseñanza ha permitido, no sólo validar su conocimiento, sino también ampliarlo con interesantes aportaciones que han enriquecido su aplicación y su potencialidad explicativa.

Los constructos de modelo mental y esquema de asimilación permiten explicar el proceso de construcción del aprendizaje significativo y, por tanto, la adquisición, la asimilación y la retención del conocimiento. La consideración de la Teoría de los Modelos Mentales de Johnson-Laird y la Teoría de los Campos Conceptuales de Vergnaud ofrece una sólida base psicológica cognitiva a la Teoría del Aprendizaje Significativo, que amplía aún más, si cabe, su poder predictivo y explicativo y su perdurabilidad, facilitando así la comprensión del proceso que conduce a la construcción de un aprendizaje significativo.

Puede concluirse, pues, que la Teoría del Aprendizaje Significativo sigue siendo un referente explicativo obligado, de gran potencialidad y vigencia que da cuenta del desarrollo cognitivo generado en el aula.

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APPLICATIONS OF A CONCEPT MAPPING TOOL

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Abstract. In this paper a general purpose tool for editing Concept Maps (CM-ED) is presented. This tool exhibits the following features: templates, views and facilities for multilingual concept maps. The tool has been used in different tasks of the Computer Aided Teaching/Learning area. Concretely: domain representation, exercise design and student model visualization.

1 Introduction

In recent years it has become apparent to many educational researchers that representing knowledge in a visual format allows one to better recognize and/or understand incoming information. It is easier for the brain to interpret data when information is presented in visual formats; visual symbols are quickly and easily recognized. Since Novak (Novak, 1977) placed concept mapping on the educational agenda, it has become an increasingly popular advanced teaching and learning tool (Bruillard & Baron, 2000).

Over the last years, and due mainly to the innovation of visual design software (Dabbagh, 2001), a number of products have emerged to support computer-based concept mapping. This kind of software enables much easier production and modification of Concept Maps (CMs) (Jonassen *et al*., 1997). Even more, some authors (Chang *et al*., 2001) argue that, as a result of their studies comparing the effectiveness of constructing CMs by paper and pencil (p&p) or by using a software product, constructing maps with a computer might be easier than constructing a map using p&p. Moreover, maintaining and revising CMs developed using p&p requires considerable amounts of time and effort Chiu *et al*. (2000), Anderson *et al*. (1998) argue that the practical advantages of constructing CMs electronically are similar to those of using a word processing program for writing. There is an ease of construction, an ease of revision, and the ability to customise maps in ways that are not possible with p&p.

In this paper a concept map editor (CM-ED) is presented together with its applications in different tasks of the Computer Aided Teaching/Learning area. Concretely: domain representation, exercise design and student model visualization.

2 CM-ED Tool

CM-ED (Concept Map EDitor) is a general purpose tool for editing CMs. The aim of the tool, implemented in Java, is to be useful in different contexts and uses of the educational agenda, concretely inside the computer-based teaching and learning area. On the one hand, it is a common concept mapping editor in which the user can draw nodes and relations generating different CMs. On the other hand, the tool can be adapted to specific purposes. The interface of the tool (see figure 1) is composed of a working area in which the CM is shown and modified. The operations are included in the menu bar, in tool bars and in contextual menus. Thus, the user can choose his/her preferred way of working. The editor also includes a notes area.

The tool allows the user to work with **templates**, which specify the kind of nodes, relations and operations that are going to be used in a set of CMs. The editor shares the same treatment for designing a CM and a template. Thus, the user defines in the template concept map the graphical characteristics of the nodes and relationships. Regarding the operations, it is also possible to restrict the operations allowed in the CM that are constructed using a concrete template. The available operations are selected also in the template concept map.

CM-ED can be specialised by means of templates. Specializing the tool means that the final tool is adapted to a template and provides less functionality but a simpler interface. This is useful, for example, when the teacher plans a concrete task for the learners. The specialized tool is restricted to the resources (types of nodes, relations and operations) specified in the template.

In order to offer a better adaptation to the user when s/he develops the CM, the interface offers the possibility of working with different **views** of the same CM. All the views share the same structure, i.e. the same nodes and relationships. However each view can have its own way of representing the nodes and relationships: graphical characteristics, spatial distributions, etc.

In addition, CM-ED is a **multilingual** tool (Larrañaga *et al*., 2003) localizable not only at user interface level but also regarding the final CMs it generates.

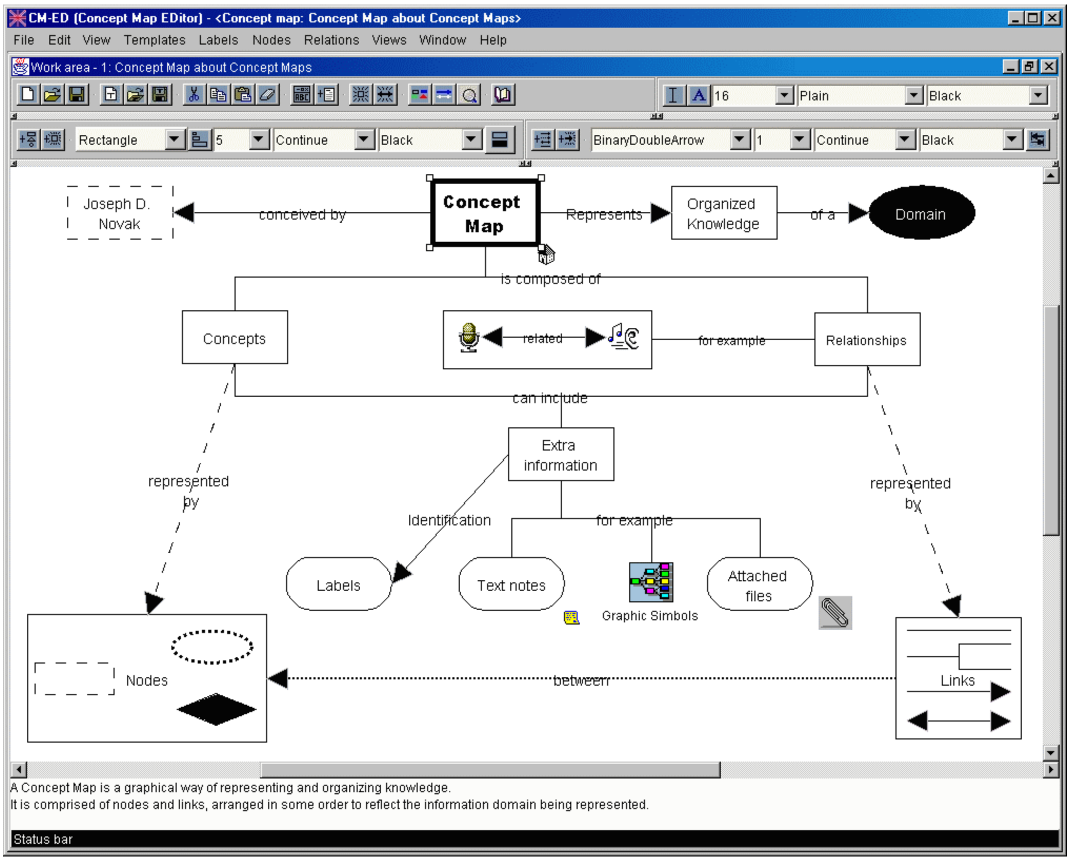

Figure 1. Interface of CM-ED.

3 Using CM-ED for acquiring the domain knowledge in IRIS

IRIS (Arruarte *et al*., 2003) is an authoring tool developed to help human instructors build intelligent teaching-learning systems in a variety of domains. Four basic elements describe the domain of all tutors built by using IRIS:

- Basic Learning Units (BLUs) or kinds of teaching-learning contents.
- Pedagogical Relationships between contents (PRs). In order to establish a pedagogical view for selecting and/or sequencing the BLUs, IRIS includes two types of relationships, structural relationships –is-a, part-of, and sequential relationships –prerequisite and next.
- Instructional Objectives (IOs) or skills to be reached. IOs refer to the application of particular skills over BLUs.
- Didactic resources (DRs). Any kind of IO needs a set of presentation resources – definitions, examples, analogies, etc.– and evaluation resources – tests, fill gaps, item sorting, etc.–.

The process of building the domain in IRIS consists of two phases. During Phase 1 the designer specifies the types of elements (BLUs), skills (IOs), relationships (PRs) and didactic resources (DRs) needed for describing the domain. During Phase 2 the concrete contents and exercises are defined. Although IRIS provides a specialised interface for acquiring each feature of the domain knowledge, this is still a difficult task for the instructional designer. Moreover, the designer can feel lost because s/he doesn't know what is done and what still has to be done. This is mainly because s/he does not have a complete view of the domain.

In order to alleviate the difficulties found in users while working with IRIS, a more intuitive and graphical interface is proposed (Rueda *et al*., 2002). Trying to help the users not getting lost, this interface minimises the use of menus and the number of different windows. CMs are the basis of the interface and CM-ED the tool that supports it. The interface shows the same appearance for both phases of using the IRIS shell.

In the first phase the instructional designer must establish the characteristics of the teaching/learning domain. This is performed by selecting the type and properties of BLUs, IOs, DRs and PRs. The result of this task will be the adaptation of the initial template of IRIS for the new tutor.

The potential of this kind of interface is shown mainly in the second phase. In this phase the user represents the complete teaching domain by means of a CM. S/he specifies the instances of BLUs and their PRs together with the DRs to teach each BLU. In order to offer more flexibility to the user when s/he develops the domain, the interface offers three working areas corresponding to different views of the same CM.

The three views, which are described below, share the same structure. In the upper left hand side of the window there are two button bars: the node types bar and the relation types bar. The set of nodes and relations of these bars are different in each view (see figure 2). In the upper right hand side there is a rubber button. The bottom of the window corresponds to the working area in which is represented the view of the CM. The user manipulates the three view windows in the same way. S/he creates new nodes by dragging and dropping the generic types of the upper side to the working area and deletes them by moving the rubber to the node. The mechanism to set relations between nodes is also simple. First the user selects the relation type and then the nodes that it connects. Relations are also deleted with the rubber.

In addition, it is necessary to include some textual information attached to each node (BLU or DR). For example the file where the text is saved in a text type DR. This information is gathered by simple forms that are open when clicking the node. Next the three views are described.

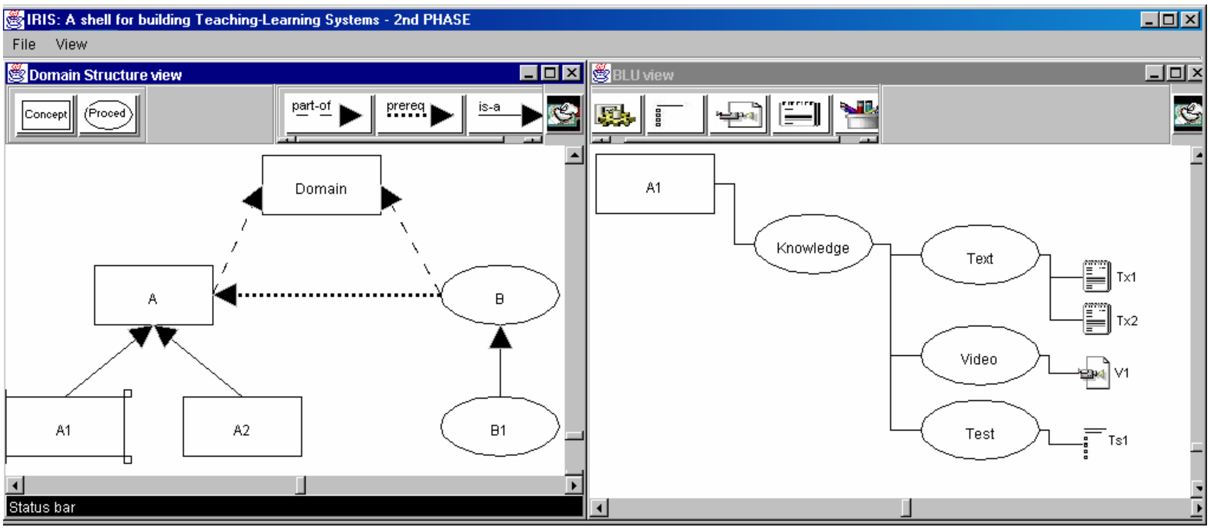

Figure 2. CM-based interface for IRIS

- The **Domain Structure view** represents the set of BLUs of the domain and the PRs between them. The components of the node bar and relations bar are those types of BLUs and PRs selected by the instructional designer in the first phase. In addition, the user can select a BLU in order to define its components in the BLU view. The left part of figure 2 represents a fragment of the domain structure of a tutor.
- The **BLU view** (right part of figure 2) shows the information related to the BLU selected in the Domain Structure view. This information is shown by a tree that represents the components of the BLU, the IOs and the DRs. The purpose of this window is to allow the user to establish the relations between BLUs and DRs.
- The **DR view** shows the complete set of resources ordered by type. In addition to the common manipulation way, the user can change the BLU related to each DR.

The recommended process to follow in the second phase starts with defining the domain at high level using mainly the Domain Structure view. Then the user is able to create the DRs and connect them to the BLUs with both the BLU view and the DR view. Nevertheless, the user can change at any moment the domain structure as well as the DRs attached to each BLU.

The system helps the process by means of a code of colours that represents the state of the nodes. The system highlights automatically nodes that are not initialised or not completely defined and also allows the user to denote those nodes that need some further attention. The system also propagates the state automatically through the CMs according to a set of rules. For example, when a DR is not completely defined, its corresponding BLU is also highlighted. The user can also attach comments to each node.

With this interface the user defines the domain by drawing a CM with a specialised tool. The tool infers a set of operations when the user performs some action on it. For example, when the user creates a new BLU, the system creates some other nodes automatically: the corresponding IOs and DRs type according with the specification made in the first phase.

4 Using CM-ED for designing exercises: MapEx

When learning about any domain it is necessary to perform different types of exercises. The selection of the appropriate exercises depends on the kind of domain and skills the learner is trying to acquire. Objective tests are one of the most widely used evaluation mechanisms not only in traditional education but also in computer assisted education. Even more, "testing components were the first to be implemented and currently are the most well developed interactive components also in Web-based education" (Brussilovsky & Miller, 1999). The easy development and evaluation of this kind of test is the main reason for their wide use. Different types of questions such as true/false, multiple choice and fill-in-gaps are recognized in already developed educational authoring tools (Reinhardt & Schewe, 1995; Arruarte *et al*., 2003; Major *et al*., 1997; Hsieh *et al*., 1999).

Although as (Cicognani, 2000) points out, concept mapping is useful in achieving some skills in the learning process, none of the revised authoring tools offer authors the possibility of creating exercises based on CMs. In other kind of learning environments, such as Internet, some concept mapping based systems have been developed. WCOMT (Tsai *et al*., 2001) is a clear example. It is a CM based testing system that provides an alternative indicator for exploring students´ understandings in physics that may differ somewhat from a traditional standard test.

The aim of MapEx is to provide a means for designing and solving graphical exercises based on CMs (Larrañaga *et al*., 2002). It is based on CM-ED and it profits from the template-based specialization. The tool has two kinds of users: teachers and learners. Teachers design new exercises or types of exercises and supervise the students' answers. The system allows the learners to solve the exercises with or without help. On the one hand, the tool can be used as an assessment tool in which the student receives no feedback. On the other hand, it can be used in a formative way allowing the learner to see correct and incorrect solutions together with the explanations that the teacher has attached to them. In both cases, the evaluation of the answers is made by the teacher and shown in the notes area. This area is used by both the teacher and the student to engage in a dialogue that supports incremental process of evaluation and development of the answer.

An exercise is an activity in which the learner answers a question drawing a CM. The task may consist of completing a CM that is provided for the student or on drawing the CM from scratch. MapEx identifies two sets of exercises: free exercises and specific purpose exercises. The degree of freedom allowed to the student when constructing the CM is different in each set. In free exercises the learner constructs CMs without any restriction in the kind of operations s/he can carry out and the types of nodes or relations s/he can use. Free exercises do not have any attached template and the student can construct her/his own template as well as the CM. Specific purpose exercises are created with a particular aim, so there are some restrictions on the resources (nodes and relations) and the operations. The restrictions of specific purpose exercises are implemented by means of a template for each kind of exercise. On the one hand, the author limits the types of nodes and the type of relations the student can use. On the other hand, it is also possible to restrict the operations on the nodes and relations allowed to the learner in the exercise. Regarding the limitations on the resources, the following exercises have been identified: taxonomy drawing, structure drawing, sorting, relation drawing and author defined exercises.

To manage exercises MapEx identifies four main objects: exercise subtypes, exercises, predefined answers and student answers, and system answer evaluations. For each exercise subtype the tool stores the following information: identification, author, associated template and date. MapEx represents instances of concrete exercises with the following: exercise identification, exercise subtype, question, an optional initial CM, the correct and incorrect predefined answers defined by the teacher and the list of the students' answers. A predefined answer is represented by a CM drawn by the author that represents a correct or incorrect solution associated with a comment with formative purposes. To represent student answers MapEx uses: answer identification, corresponding exercise, student, the CM that represents the student answer and a flag indicating the state of evaluation.

MapEx for the teacher: MapEx allows teachers to define exercises and to supervise the answers of the students through a Multiple Document Interface composed of the following windows:

- **Exercise management window**. A CM representing the classification of exercises types, subtypes and instances is shown. This window allows the author to create, modify or eliminate subtypes, instances and solutions of exercises. To create a new subtype of exercise the author has to specialise the default template attached to the selected type using the template management window. The creation of exercise instances implies the definition of an optional initial CM and the correct and incorrect answers. The author will use the exercise window for these tasks.
- **Template management window**. In this window, the author specifies in a CM the type of nodes, relations and operations allowed to the learner when working with the exercise. This window is used to create an author-defined exercise or to create an exercise subtype.
- **Exercise window**. This window allows the author to define an exercise, writing the question and drawing the initial CM when necessary. Thus CM is based on a template and, therefore, the window is a specialized version. However, the author is not restricted to the operations of the template. The teacher can define correct and incorrect answers through the answer window and use the note area to describe the exercise.
- **Answer window**. This window is also specialized to a template. It has two uses for the teacher. First it will be used to define the correct and incorrect solutions, and it can include explanations in the note area that will be shown to the student with a formative aim. Second, the teacher will supervise the answers of the student through this window. The approach for the evaluation that the tool supports is based on a negotiation between teacher and learner. The note area will be used to implement the communication between them.
- **Supervision window**. In this window the tool shows the list of students with the answers each student has drawn for the exercises s/he made. Clicking in the node, the corresponding CM will be shown so that the teacher can mark it and write notes for the student. The nodes of the answers also have attached flags meaning that the exercise is new or that it has a new comment of the teacher or of the student.

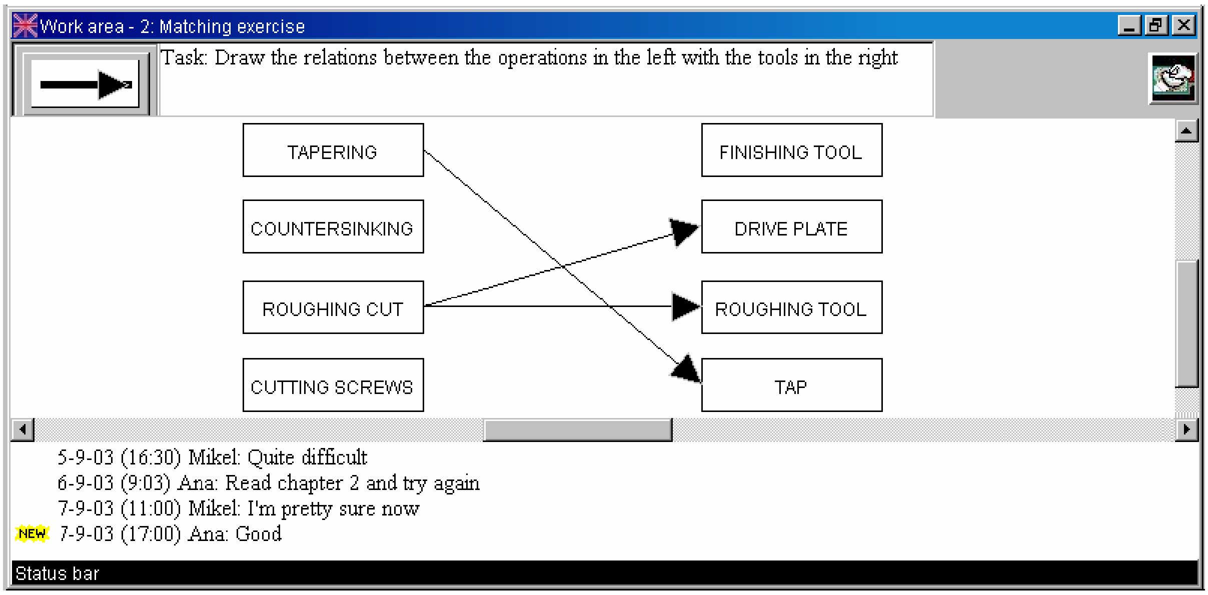

Figure 3. Interface for solving exercises

MapEx for the learner: The tool allows the learners to select the exercise to solve and to draw the corresponding answers. In addition, the student can get involved in a dialogue with the teacher on an exercise or evaluation. MapEx offers students a Multiple Document Interface composed of the following windows:

- **Exercise browser**. In this window the learner selects the exercise to work on. S/he can answer the exercise in the answer window. Exercises have attached flags for the following situations: new exercise, new comment from the teacher, new comment of the student and finished exercise.
- **Answer window**. It is shared with the teachers and supports the communication between them. This window has three uses for the learner. During the resolution of the exercises, MapEx presents the exercise formulation to the learner and it allows him/her to draw the answer in the specialized CM window. When the exercise is being evaluated it is the means of communication between student and teacher and will support the negotiation and also the instruction of the learner. Finally, the student can observe, using this window, the correct and incorrect answers defined by the teacher. Figure 3 corresponds to a relation drawing exercise in which the student has to complete an initial CM establishing the relations between operations and tools. The student is only allowed to create and delete relations.

5 Using CM-ED for representing the student: DynMap

Up to now, several authors have considered visualization and inspection of student models (WS, 1999). This component collects the learning characteristics of the student and his/her evolution during the whole learning process. Open Learning Modelling can be viewed as an attempt to directly involve learners in the diagnosis process and, as a result, infer their knowledge about the target teaching/learning domain (Dimitrova, 2002).

Commonly, systems built following the approach of Open Learner Modelling allow us to externalise the student model and, in some cases, provide mechanism for both teachers and learners, to change the content of the models. The efforts range from simply visualizing the model, to actively involving the student in the modelling process through negotiation or collaborative construction of the model. The model is not just a source of knowledge about the student valuable for the system, but becomes an important learning resource on its own (Hartley & Mitrovic, 2002). Kay (2001) collects some of the reasons that different authors argue for making the learner model available: users should have access to and control over personal information, correctness of the model can be assessed by the user, access to the learner model improves the learner’s appreciation of the system’s learning goals, programmer accountability is enhanced if the programmer knows the learner will have access to the model, there is merit in making complex systems more comprehensible, and finally, and importantly, an accessible learner model may aid learning by supporting reflection and planning.

Cook & Kay (1994) make one of the first attempts to represent graphically the learner model; they use a mixture of text and conceptual trees based diagrams. Morales *et al.* (1999) present a table-like graphical representation format of the learner model for a sensory-motor task in which every row represents a rule. Bull & Nghiem (2002) claim that the use of simple learner models, easy to represent in different ways, e.g. graphical and tabular, allows teachers and students a better understanding of the students’ learning of a target domain. VisMod (Zapata-Rivera & Greer, 2000) provides a flexible architecture where students and teachers can create their own views of a student model by choosing nodes they want to inspect from the Bayesian network that represents the student model. In addition, Dimitrova *et al.* (2002) justifies an approach of inspecting and discussing the learner model in a graphical manner using conceptual graphs. They argue that the selection of an appropriate communication medium reduces comprehension problems, facilitates reasoning about learner’s behaviour, and promotes metacognitive processes. Finally, the tool CourseVis (Mazza & Dimitrova, 2003) processes student data collected by web-based course management systems and creates pictorial representations (2D and 3D) to help instructors gain understanding of social, cognitive and behavioural aspects of distance students.

The main goal of DynMap is to show graphically the knowledge of the students through the learning process to both the student and the teacher (Rueda *et al*., 2003). Although the main and initial purpose was to present the internal student model of an ITS it is also applicable to other kinds of teaching/learning systems and even to other educational contexts. It includes specialized tools for inspecting the student model addressed to both kinds of users: teachers and students. It uses the core of CM-ED adapted by means of a template.

DynMap represents the knowledge of the student in a CM following the overlay approach (Golstein, 1982). The main characteristic of an overlay approach is that the knowledge that a student has about a domain is represented as a subset of the whole domain. The domain module represents the curricula to be transferred to the student in a CM and provides the basis for the graphical view of the student knowledge. Therefore, the student model is a subset of the CM of the domain that includes those concepts that the student has learnt or is learning.

Taking into account that the student's knowledge changes along the learning process it is important that the student module reflects this evolution. Unlike most of the revised student models, DynMap is able not only to keep the current state of the student knowledge but also to record the evolution of the student through the learning sessions. This feature is used to show dynamically the sequence of states of the student model.

DynMap is composed of a knowledge base that maintains the set of students concept maps, the DynMap Repository, and four functional modules: Translator, DynMap Builder, Student-DynMap and Teacher-DynMap. The translator is a piece of code to be integrated into the student data source while DynMap Builder, Student-DynMap and Teacher-DynMap constitute an independent Java application.

DynMap Repository. This repository manages the storage of the dynamic evolution of all the students' CMs. The **Student Concept Maps** (SCMs) are stored after each learning session and the changes performed on it while the session is carrying out in the Operations Log file. An **Operation Log** contains the sequence of operations performed in a session and the time when each one was done. Therefore, the **Dynamic Student Concept Map** (DynSCM) is composed of a sequence of SCM and Operation Logs.

Translator. This module is responsible for connecting the data source about the student with the inspection tools. As said before, this data source can be different, an Intelligent Tutoring System, an Open Learning System, a tool for managing marks of students in classic teaching, etc. Therefore, the translator is a piece of code integrated into the data source written in a programming language appropriate for that data source. It translates the internal learner model to an intermediate representation in XML that can be processed by DynMap.

DynMap Builder. This module is responsible for reading the XML files containing the data of the students and creating the CMs that represent them. It uses the CM of the domain as the skeleton of the student model and represents the individual data of the learner.

Teacher-DynMap. This component allows the teacher to select the student to observe by means of a browser. Then, the teacher can observe the DynSCM that represent the beliefs of the system about the current state and the evolution of the student's knowledge. Using a set of video-like buttons of a tool bar the user can move through the student's learning process. The bottom part of the Teacher-DynMap has the note area. This will support communication between the teacher and the student.

Student-DynMap. The student viewer is simpler. The student's inspector allows the learner to observe the CM that represents the current beliefs of the system about his/her knowledge.

6 Conclusions

Throughout this paper the authors have shown the potential of Concept Map EDitor (CM-ED) in different tasks of the Computer Aided Teaching/Learning area. These applications use the core of CM-ED adapted by means of templates.

CM-ED has been used inside an authoring tool to specify the domain knowledge of intelligent teaching-learning systems.

MapEx allows the generation and solving of graphical exercises based on CMs. The tool has two kinds of final users: authors and students. On the one hand, teachers or curriculum designers define free exercises, exercises without any restriction, and specific purpose exercises, exercises with particular aims. On the other hand, students solve the proposed graphical exercises creating or completing CMs. MapEx can be used as an assessment tool in which the student receives no feedback or in a formative way allowing the learner to see correct and incorrect solutions together with attached explanations. In both cases, the evaluation of the answers is made engaging the teacher and the student in a dialogue that supports an incremental process of evaluation and development of the answer.

DynMap is a system for showing graphically the knowledge of the students through the learning process by means of CMs. It has two types of potential users: teachers and students. On the one hand, teachers can observe the dynamic evolution of the student and the state of the learner model at any time of the learning process. On the other hand, students are allowed to observe what the automatic tutor knows about their current knowledge.

Finally, CM-ED has been used in other areas such as Natural Language Processing. Concretely it has been integrated in Abar-Hitz, an annotation tool for the Basque Dependency Treebank (Diaz de Ilarraza *et al*., 2004).

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EXAMINING CONCEPT MAPS AS AN ASSESSMENT TOOL

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Abstract. In this paper, I describe concept maps as assessment tools for measuring one aspect of achievement, the organization of declarative knowledge in a domain. A concept map-based assessment consists of a task that elicits connected understanding, a response format, and a scoring system. Variation in tasks, response formats, and scoring systems produce different mapping techniques that may elicit different knowledge representations, posing construct-interpretation challenges. The paper provides a framework to guide the research on the technical quality of this tool. It will briefly describe some of the studies conducted and it will focus on some of the dimensions that can be used to define the assessment task.

1 Introduction

Cognitive psychologists posit that, "the essence of knowledge is structure" (Anderson, 1984, p. 5). Assuming that knowledge within a content domain is organized around central concepts, to be knowledgeable in the domain implies a highly integrated conceptual structure among those concepts. This means that as expertise in a domain grows, through learning, training, and/or experience, the elements of knowledge become increasingly interconnected (cf. Chi, Glaser, & Farr, 1988). Researchers have taken different representational approaches to capture this organizational property of knowledge (e.g., Goldsmith, Johnson, & Acton, 1991; Novak & Gowin, 1984; Novak, Gowin, Johansen, 1983; White & Gunstone, 1992). Among these approaches, concept maps have been proposed as a more direct approach (see Ruiz-Primo & Shavelson, 1996) for capturing the interrelatedness among concepts in a domain. It can be easily argued that the dimension of structure of knowledge yielded by concept maps is unique in comparison to traditional achievement tests.

The technology for developing, using, and evaluating concept maps as an assessment tool is currently being investigated. Over the past eight years, we have done research intended to inform a concept map-assessment knowledge base (Ruiz-Primo & Shavelson, 1996; Ruiz-Primo, Schultz, & Shavelson, 1996; Ruiz-Primo, Schultz, & Shavelson, 1997; Ruiz-Primo, Schultz, Li, & Shavelson, 2001; Ruiz-Primo, Shavelson, Li, & Schultz, 2001; Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, in press). Our goals have been to provide not only evidence about reliability and validity of concept map assessments, but also to provide a framework that can guide further research in this area.

This paper focuses on issues related to the development and technical examination of concept maps as assessment tools. First, I present a framework that can be used to guide the design of concept map assessments. Then, I discuss the approaches we have used to examine the technical qualities of concept maps as assessment tools. In the third part of the paper, I discuss some issues related to the use of concept maps as an assessment tool. Finally, I drew some general conclusions about what we have learned about concept map assessments and what still needs to be done.

2 Conceptualizing Concept Maps as Assessment Tools

A concept map as an assessment can be thought of as a set of procedures used to measure important aspects of the structure/organization of a student's declarative knowledge. The term "assessment" reflects the belief that reaching a judgment about an individual's achievement in a domain requires an integration of several pieces of information. Concept maps based assessment is only one of those pieces (see Cronbach, 1990).

Formally, a concept map is a graph consisting of nodes and labeled lines. The nodes correspond to important terms (representing concepts) in a domain. The connecting lines denote a directional relationship between a pair of concepts (nodes). The label on the line (explanation) conveys how the two concepts are related. The combination of two nodes and a labeled line is called a proposition. A proposition is the basic unit of meaning in a concept map and the smallest unit used to judge the validity of the relationship drawn between two concepts (e.g., Dochy, 1996). Concept maps, then, purport to represent some important aspects of a student's declarative knowledge in a content domain (e.g., physics).

We (Ruiz-Primo & Shavelson, 1996) characterized concept maps assessments in terms of: (a) a task that invites a student to provide evidence bearing on his or her knowledge structure in a domain, (b) a format for the student's response, and (c) a scoring system by which the student's concept map can be accurately and consistently evaluated. Without these three components, a concept map cannot be considered as a measurement tool. This characterization made evident the variation in concept mapping techniques used in research and practice (Ruiz-Primo & Shavelson, 1996).

The importance of comparing different concept map assessment techniques might be better understood if we consider the relationship among the three assessment components (Figure 1). Threats to validity exist at almost every connection, because every connection is established based on assumptions and the model cannot work unless all the assumptions are valid. For example, assessment tasks not only elicit but also influence students' responses. That is, the characteristics of the assessment tasks may make students respond in ways that are not relevant (e.g., guessing) to the construct assessed, or may be too narrow that it fails to tap important aspects of the construct (e.g., the assessment task is too structured). The same can be said about the scoring system. A deficiency in the scoring system may preclude the ability to properly or sufficiently capture information about the quality of students' responses. Research on the variations in concept map assessments techniques is critical.

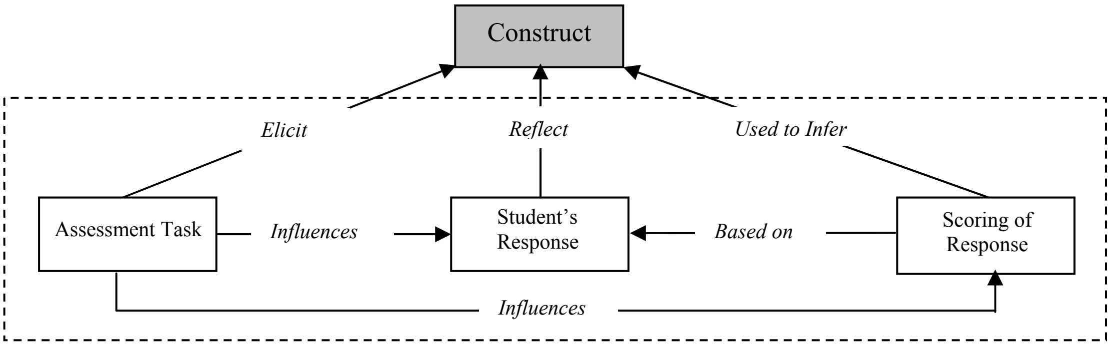

Figure 1. Interaction among assessment goals and assessment components (After Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, internal document).

2.1 The Nature of Concept Map Assessment Tasks, Response Formats, and Scoring Systems

In previous research, we identified the map components provided to the student as a dimension for determining the demands of the mapping techniques. A concept map task assessment could be characterized along a directedness continuum from high-directed to low-directed based on the information provided to the students. High-directed concept map tasks provide students with the concepts, connecting lines, linking phrases, and the map structure. In contrast, in a low-directed concept map task, students are free to decide which and how many concepts they include in their maps, which concepts are related, and which words to use to explain a relationship. The mapping techniques studied in our research have been selected at different points on a directedness continuum (Figure 2). Indeed, we have provided evidence that different mapping techniques do not provide the same information about the students' connected understanding (Ruiz-Primo, Schultz, Shavelson, 1996; Ruiz-Primo, Schultz et al., 2001; Ruiz-Primo, Shavelson et al., 2001; Yin et al., in press). Based on information collected across studies it is clear that directedness involves more aspects that need to be considered in deciding the characteristics of the mapping assessment tasks. In what follows, I explore other aspects that can be considered in deciding the demands of mapping assessment tasks.

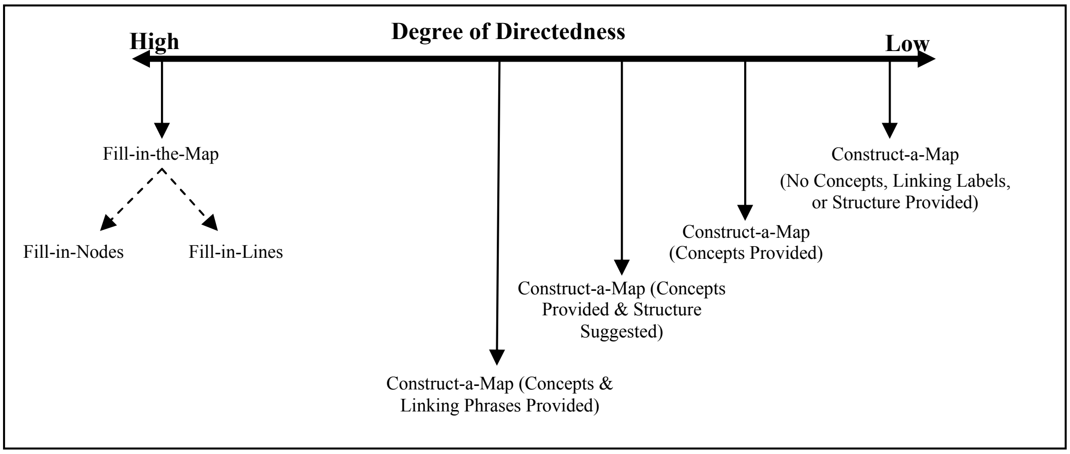

Figure 2. Concept map techniques studied according to directedness of the mapping tasks.

I believe that in order to better determine the cognitive demands evoked by different mapping techniques, it is important to consider not only what is provided, but also the extent/amount of what is provided, the significance of what is provided, and what is required from the examinees. In Figure 3, I propose a framework that takes into consideration different aspects of the nature of the tasks, the response format, and the scoring system. It provides a picture that considers some possibilities involved in deciding the characteristics of the assessment mapping techniques.

Admittedly, the interpretation of Figure 3 is complex. In the figure, the assessment components are shaded. The decisions made about the mapping task and the scoring system are directly related to the map components - what components are provided and with what characteristics, and what is scored. The response format is directly linked to the constraints imposed in the task. I provide an example that may help to understand the rationale of the figure. I focus only in one of the map components, *the terms* (concepts). In designing a concept map assessment, an assessor decides to provide the examinee with the terms to be used in the map, but she has to make another decision about whether to provide only a *sample* of terms or *all* of the terms to be used. Furthermore, if only a sample of terms is provided, the assessor needs to decide which terms should be provided among the ones considered relevant within a particular domain and topic. Terms provided by the assessor in the sample might be *key* (most relevant) terms or only *related* but not key terms. With only a sample of terms provided, the assessor may require from the examinee to provide only a few terms (say, ten) or all the terms the examinee considers as appropriate within a topic. In addition, the assessor should decide whether the terms the examinee provides should be key (most relevant) terms within the topic at hand or only related terms. All these decisions will guide some of the characteristics of the scoring system. If the examinee is to provide the terms, the assessor may decide to score them as correct or incorrect without considering the relevance of the terms. If amount of terms was not posed as a constraint, the assessor may score the quantity of terms provided (extent of the concepts the examinee connects/relates within a topic). If a criterion map is used for scoring, not only other dimensions of the examinee's response (e.g., similarity) should be considered; also, the correctness, relevance and quantity of the map will be determined, somehow, by the characteristic of the criterion map at hand. All these decisions may lead to different score interpretations. Rice, Ryan, and Samson (1998) have suggested that different methods of scoring maps within the same technique may be measuring different constructs of aspects of the domain.

An assessor, of course, can decide to provide all the components, fully or only partially (i.e., a sample of concepts, connections, explanations, and a partial structure of the map). The decisions made within each of the components will be also multiple within each component. Consider, for example, the scoring implications of providing linking phrases from which students will select the ones to be used to connect a pair of terms. If linking phrases are not selected carefully, students are very likely to obtain bipolar scores, which do not reflect the quality of their knowledge.

Assessment Components		Concept Map Components: Terms (Concepts)	Linking Lines (Connections)	Linking Phrases (Explanations)	Structure (Spatial Arrangement)
Response Required	Task				
Construct the Map	What is Provided	Not Provided / Provided	Not Provided / Provided	Not Provided / Provided	Not Provided / Provided
	How Much is Provided	Few Provided All Provided	Few Provided All Provided	Few Provided All Provided	Partially Provided Completely Provided
	Relevance of What is Provided	Key Terms Related but not Key Terms	Very Relevant Not Relevant	Deep Phrases Superficial Phrases	Very Relevant Related but not Relevant
Fill-in the Map	What is Required	Few Terms – All Terms Provide Terms – Select Terms Key Terms – Related but not Key Terms	Few Lines – All Appropriate Lines Most Relevant Lines – All Suitable Lines	Few Phrases – All Phrases Provide Phrases – Select Phrases Deep Phrases – Superficial Phrases	Free Structure Specific Structure
	Scoring System				
	Use of a Criterion Map	Not Used / Used	Not Used / Used	Not Used / Used	Not Used / Used
	What it is scored	Correctness Relevance Quantity / Correctness Relevance Quantity Similarity	Correctness Relevance Quantity / Correctness Relevance Quantity Similarity	Correctness Quality Quantity / Correctness Quality Quantity Similarity	Complexity Type / Complexity Type Similarity

Figure 3. Framework considering some aspects about the nature of the mapping assessment tasks, response formats, and scoring system.

Making obvious the aspects that can be considered in designing a mapping assessment task makes two issues evident: (1) The *end product* of a concept map assessment – the map – can be conceived of as a continuum that goes from a map fully constructed by the students to a map only filled-in by the student,[1] and (2) within each type of end-product, the possibilities that can be considered in the design of a map assessment are multiple. A map completely constructed by the student may vary on what map components are provided, how much it is provided within each component, the characteristics of what is provided, and what is required from the student. Still, notice that although the end-product may be identical - a map completely constructed by the student - the cognitive demands evoked by diverse constraints are different.

In addition to the complexity of these decisions, there is the issue of response mode, what we have called the "method of assessment" in performance assessments. Are paper-and-pencil and computer-based concept

[1] Think, for example, of a mapping technique in which the examinee is provided with an "unfinished" map that s/he has to complete. Another example in the continuum closer to the fill-in-the-map can be the case in which the examinee fills-in the partially structure of the map provided but s/he will also finish the construction of the map.

map assessments exchangeable? Are interpretations across methods the same when using the same mapping technique? This is a research topic that also deserves a long research agenda in its own right.

3 Evaluating the Technical Quality of Concept Map Assessments

Intuitively, the use of concept maps to evaluate student declarative knowledge structure is appealing. A student's map directly reflects, to some degree, a student's understanding in a domain. Consensus needs to be reached not only about to what concept map assessments are but also about whether they provide reliable and valid measures of students' knowledge structure (Ruiz-Primo & Shavelson, 1996). That is, interpretation of assessment scores needs to be evaluated conceptually and empirically. In our work, these claims focus on both observed performance and cognitive aspects. We have conducted a series of studies to evaluate the information provided by concept maps. As mentioned, we have focused on the equivalence of different mapping techniques.

Most of the studies we have conducted involve repeated measures. Students are assessed across different mapping techniques and/or across the same mapping technique but with different samples of concepts. The former approach focuses on evaluating whether different mapping techniques provide a "similar" picture of students' connected understanding (a validity issue). The latter, examines concept-sampling variability (a reliability issue). We found that little attention has been paid to this latter issue (e.g., Ruiz-Primo & Shavelson, 1996). Hence, in our studies we have randomly sampled concepts whenever possible. We have conducted two types of empirical analyses, those based on quantitative analyses, and those based on cognitive analyses.

3.1 Empirical Quantitative Analyses: The Use of Generalizability Theory

Empirical quantitative analyses of concept map scores have been conducted within the context of Generalizability (G) theory. G theory recognizes that multiple sources of error contribute to the unreliability of a measure and hence to the estimate of student performance (e.g., Shavelson & Webb, 1991). The sampling framework we have used in our research defines and integrates the following facets: mapping techniques, raters, terms (i.e., concepts), and propositions. G theory has been used to evaluate the generalizability of students' average score map scores over mapping techniques, raters, concepts, and propositions. Different facets have been included in different studies; however, we have acknowledged that other facets, which we have not studied yet, can be included in the framework (e.g., occasions, method of response mode).

Results across all the studies using the construct-a-map technique suggest the following good news about concept map scores: (1) Students can be trained to construct concept maps in a short period of time with limited practice. (2) Raters do not introduce error variability into the scores. Concept maps can be reliably scored even when complex judgments such as quality of proposition are required (the interrater reliability on convergence score averaged across studies is .96). (3) Sampling variability from one random sample of concepts to another provides equivalent map scores when the concept domain is carefully specified. It is possible that the procedure we have followed in selecting the concept domain helped to create a list of cohesive concepts, therefore, any combination of concepts could provide critical information about student's knowledge about a topic. (4) The high magnitude of relative (.91) and absolute (.91) coefficients, averaged across types of scores and studies, suggest that concept maps scores can consistently rank students relative to one another and provide a good estimate of a student's level of performance, independently of how well their classmates performed. (5) The proportion of valid propositions in the students' map out of the possible propositions in a criterion map seems to better reflect systematic differences in students' connected understanding than other scores and it is the most effort and time efficient indicator. Other procedures have been carried out for supporting score interpretations (e.g., comparison between experts and novices scores).

3.2 Empirical Qualitative Analyses: Cognitive Validity

Cognitive validity studies help to link the intended assessment task demands, the cognitive activities evoked, and the student's performance level (Ruiz-Primo, Shavelson, Li, & Schultz, 2001). We have sought to bring empirical evidence to bear on the: (1) cognitive activities evoked by different mapping techniques, (2) relationship between the cognitive activities and performance scores, (3) impact of variation in assessment task on cognitive activities, and (4) correlations between assessment measuring similar and different constructs. The strategy is represented in Figure 4.

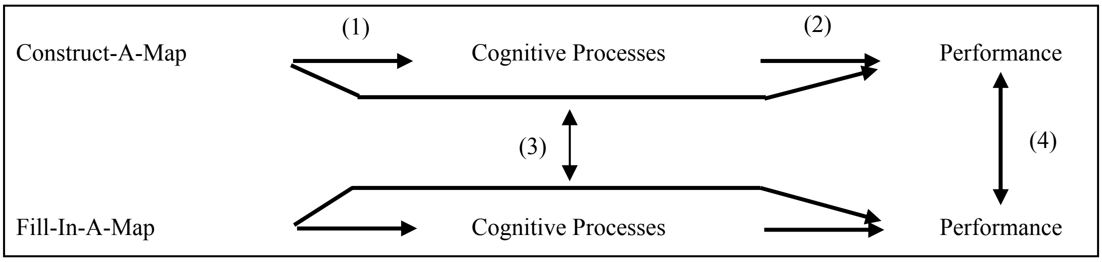

Figure 4. An approach to empirically evaluating cognitive interpretations of concept maps (Adapted from Ruiz-Primo, Shavelson et al., 2001).

We (Ruiz-Primo, Shavelson et al., 2001; Yin, et al., in press) have used talk-aloud protocols to capture experts' and novices' cognitive activities while concept mapping. We have briefly trained experts and novices to talk aloud while they are performing an unrelated task. Once they are comfortable talking aloud during the irrelevant task, we ask them to talk aloud as they are engaged in the concept-map assessment tasks while their verbalizations are recorded. If the student forgets to verbalize her or his thoughts, the researcher reminds her or him to talk aloud. In a recent study (Yin, et al., in press) we also video-taped participants' actions. The rationale behind this decision is that audio recoding may lead to ambiguous information. We have analyzed concept map talk aloud protocols using two approaches: In Approach 1, verbal protocols are transcribed, segmented, and coded. Codes follow from the construct definition and the logical analysis of the assessment demands. In Approach 2, we have examined the overall pattern of proposition generation.

In Approach 1, we (Ruiz-Primo, Shavelson et al., 2001) have distinguished between micro- and macro-levels of the protocol analysis. At the microlevel, we coded *explanations* (e.g., "N_2O_2 is a molecular compounds because they are both nonmetals," p. 115), *monitoring* ("I can't remember exactly what this is"; p. 115), *conceptual errors* reflecting misconceptions ("molecules are atoms"), and *inapplicable events* (e.g., reading instructions). At the macrolevel, we coded *planning* (verbalizations at the start of each protocol; e.g., "I will read the concepts and select the most important concept to put … in the center"; p. 116) and *strategy* (from entire protocol) for working through the mapping exercise. At the macrolevel, we used the entire verbal protocol evoked by a particular mapping technique. However, for the microlevel analysis, we segmented verbal protocols into fine-grained response entries (as small as phrases). On average, inter-coder reliability for the microlevel analysis was high across the different mapping techniques (construct-a-map, fill-in-the-nodes, and fill-in-the-lines). Both percent agreement and agreement adjusted for chance agreement (Kappa) were reported at the macrolevel with a range of 86 to 100 percent agreement and 71 to 100 percent adjusted.

In Approach 2, we have focused on two aspects of proposition generation: rate and procedures. *Proposition generation rate* refers to the speed with which students constructed propositions. *Proposition generation procedures* refer to the steps students take in proposition construction. We have attempted to infer how the nature of the assessment task influences students' cognitive processes by comparing their proposition generation rates across mapping techniques.

We (Ruiz-Primo, Shavelson et al., 2001) conducted an study to evaluate the interpretation of scores from three mapping techniques: (1) construct a map from scratch using concept provided, (2) fill-in-the-nodes in which students filled in a 12-blank-node skeleton map with concept provided, and (3) fill-in-the-lines, in which students filled a 12-blank-line skeleton map with linking phrases provided. To infer cognitive activities of three types of examinees (teachers, high proficient students, and low proficient students) we examined concurrent and retrospective verbalizations using Approach 1. We concluded that the three mapping techniques provided different pictures of students' connected understanding, and inferred cognitive activities across mapping techniques differed in relation to the directness of the task and the expertise of the examinees.

In another study, we (Yin at al., in press) examined the equivalence of another the two mapping techniques: Construct-a-Map (CMC) with own created linking phrases and Construct-a-Map with selected linking phrases (CMS). In this study, we used Approach 2 to infer cognitive activities. We used the students' think-aloud protocols to illustrate the cognitive procedures leading to the proposition generation rate differences. A comparison of the cognitive processes revealed that students in CMS spent extra effort and time matching what linking phrases they *wanted* to use with what they *could* use to construct their maps. Consequently, students in the CMS condition constructed their maps more slowly than students in the C condition. After all the evidence was analyzed, we concluded that the CMC and CMS mapping techniques were not equivalent for the total accuracy score. The two concept-map task techniques elicited different student responses and representation of the students' declarative knowledge structure.

4 Conclusions

There is potential in using concept maps as assessment instruments, at least from the technical quality perspective. Nevertheless, there are still some issues that need to be resolved before we can conclude that they can reliably and validly evaluate students' connected understanding, especially if concept maps are to be used in high stake accountability contexts (cf. Lomask, Baron, Greig, & Harrison, 1992).

It is clear that we need to invest time and resources in finding out more about what aspects of students' knowledge are tapped by different forms of concept map assessments. Which technique(s) should be considered the most appropriate for large-scale assessment? Practical issues, though, cannot be the only criterion for selection. We have shown that the constraints and affordances imposed by different forms of assessments affect the student's performance. This means that different mapping techniques may lead to different conclusions about students' knowledge.

Many questions remain to be studied. For example, how large a sample of concepts is needed to measure a student's knowledge structure? How stable are concept maps scores? How exchangeable are concept mapping techniques that use different response modes (e.g., computer simulations versus paper-and-pencil). This research agenda is long, yet necessary, if we want to test in full the potential of concept maps as instruments for measuring different aspects of achievement in a particular domain.

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DISEÑADOR DE MAPAS CONCEPTUALES: UNA HERRAMIENTA IMPLEMENTADA CON Y PARA EL USUARIO FINAL

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Abstract. El uso de los Mapas Conceptuales como herramienta para apoyar el aprendizaje significativo de los aprendices ha sido materia de estudio en los últimos veinte años. Diversos estudios han evaluado el impacto de esta técnica pedagógica en las más diversas áreas del quehacer humano. Tal vez uno de los temas menos estudiados formalmente sea la construcción de herramientas basadas en tecnología digital que den soporte al trabajo con mapas. La idea es muy poderosa, ya que con estas herramientas como soportes o infraestructuras, el proceso de usar mapas para apoyar el cambio en el significado de las experiencias de los aprendices puede permitir centrarse en los mapas como herramientas de construcción de significado. Este estudio tiene por finalidad presentar un diseñador de Mapas Conceptuales, dMC, software que ha sido diseñado y rediseñado a partir de las necesidades de profesores del sistema escolar Chileno, que usan los mapas en su práctica pedagógica cotidiana. Estos profesores, que además utilizan permanentemente las Tecnologías de la Información y Comunicación, han diseñado, sobre la base de su experiencia y trabajo de aula, los requerimientos de un software que se ajuste a sus necesidades e intereses, así como también que responda a requerimientos culturales implícitos en escuelas y liceos de Chile. Luego de elaborar el software, los profesores evaluaron su usabilidad pedagógica y expertos evaluaron la usabilidad técnica. Todas estas evaluaciones han permitido realizar rediseños para culminar con una herramienta que se ajuste a las necesidades de los profesores en su trabajo pedagógico con los alumnos para estimular la construcción de significados.

1 Introducción

En la última década se implementan en Chile diferentes programas orientados a mejorar la calidad y equidad de la educación. Estas transformaciones profundas desembocan luego en una Reforma Educacional, que innova paulatinamente las formas de enseñar y aprender, los contenidos de la educación, la gestión de los servicios educativos, los materiales educativos, la infraestructura escolar, el financiamiento del sector, y el mejoramiento sostenido de las condiciones de trabajo de los docentes. Junto a ello, se traslada la importancia que tradicionalmente se le ha dado a la enseñanza, a una mayor relevancia y protagonismo del aprendizaje y sus procesos. Ello implica un cambio en el rol del profesor que centraba su tarea en que los alumnos aprendieran la información que les transmitía en clases, que "recordaran" lo que les había enseñado, pues ello daba fe de que dichos contenidos habían quedado en sus mentes.

Es así como durante los últimos ocho años ha surgido en las escuelas y los liceos de nuestro país, la necesidad de poner en práctica nuevas metodologías, estrategias y técnicas, que den un giro a la concepción tradicional de mirar el aprendizaje y con ello el papel de profesores y alumnos.

El aprendizaje significativo es un buen punto de partida a la hora de poner en práctica estas innovaciones. El niño aprende un contenido sólo cuando es capaz de atribuirle significados profundos, dependiendo de sus estructuras cognitivas y experiencias previas. El aprendizaje significativo implica que el niño 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, Novak y Hanesian, 1978).

La puesta en práctica del aprendizaje significativo resulta compleja y requiere de un dominio de las estrategias y técnicas que permitan visualizar los logros y la construcción de significados. Una de las técnicas más representativas y que se basa en esta concepción teórica, es la técnica de los Mapas Conceptuales. Novak ha señalado que los Mapas Conceptuales tienen por objeto representar relaciones significativas entre conceptos en forma de proposiciones. Se basan en la teoría de aprendizaje significativo y constituyen una técnica para representar la elaboración de esquemas mentales de aprendizaje (Novak y Gowin, 1984; Novak, 1977, 1998). Un Mapa Conceptual es una expresión gráfica de las relaciones de un conjunto de conceptos y la naturaleza de estas (Sánchez, 2001). 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.

Los Mapas Conceptuales son utilizados en diversas actividades que requieren utilizar, representar y gestionar el conocimiento. El valor didáctico de los Mapas Conceptuales en el aprender está en "revelar la organización cognitiva del estudiante y sus concepciones espontáneas" (Novak y Gowin, 1984), elemento fundamental para poner en práctica los propósitos de las nuevas tendencias educativas implementadas en nuestro país.

Otro elemento clave de la Reforma ha sido el acceso que los profesores han tenido a tecnologías de la información y comunicación, TICs. El Ministerio de Educación ha desarrollado una red nacional de Informática Educativa, Enlaces, que durante 12 años ha dotado de infraestructura computacional a casi la totalidad de las escuelas y liceos públicos del país. Dicha infraestructura es complementada con acciones de capacitación y asistencia técnica a los docentes en el uso e integración curricular de las TICs. Nuestro Centro es uno de los centros ejecutores de la Red Enlaces y ha capacitado desde 1997 a cerca de mil profesores, en el uso básico del computador y la integración de las TICs al curriculum. Uno de los contenidos de nuestra capacitación es justamente la Integración Curricular de las TICs, donde los profesores aprenden teoría y práctica de los Mapas Conceptuales como herramientas que se ajustan muy apropiadamente a los propósitos de la Informática Educativa en el aprendizaje.

Es en este sentido que hemos implementado diferentes iniciativas para incorporar software para la elaboración de Mapas Conceptuales existentes en el mercado, tales como Inspiration (http://www.inspiration.com) y en menor medida, CmapTools (http://cmap.ihmc.us/), ConceptDrawMINDMAP(http://www.conceptdraw.com),PiCoMap(http://www.goknow.com/Products/PiCoMap/) y VisiMap (http://usuarios.iponet.es/casinada/21vmap.htm), como software orientados a la construcción de Mapas Conceptuales. Asimismo, hemos utilizado aplicaciones iniciales de Mapas Conceptuales en ciencias (Sánchez, 1994; Sánchez y Mallegas, 1995).

Sin embargo, en la práctica cotidiana observamos que este software no es utilizado por los profesores por diversas razones: el costo de la mayoría de estas herramientas es elevado para una escuela (a excepción de CmapTools), varios de ellos presentan requerimientos de hardware que no están disponibles, y en su mayoría son software escritos en el idioma inglés. Asimismo, los profesores manifiestan que algunas de ellas no son herramientas orientadas a la construcción de software para el aprender, por lo tanto cuando quieren utilizar la técnica de los Mapas Conceptuales aplicada a actividades de aprendizaje específicas, se encuentran con funcionalidades que incluso interfieren con aquello que los alumnos entienden y comprenden de un Mapa Conceptual. Ante ello, frecuentemente escuchamos que profesores y alumnos manifiestan la necesidad de contar con una herramienta tecnológica que les ayude y apoye el aprendizaje y la práctica pedagógica diaria.

Este estudio está orientado a diseñar un software de Mapas Conceptuales con y para el usuario final. Inicialmente evaluamos los requerimientos de profesores que habitualmente utilizan Mapas Conceptuales como estrategia metodológica de aprendizaje con sus alumnos y que sabemos poseen un alto dominio en el uso de las TICs como apoyo al aprender. Luego, a partir de los resultados de esta evaluación, diseñamos un software, Diseñador de Mapas Conceptuales, dMC, que permita la creación y construcción de mapas de manera fácil y funcional al contexto y los requerimientos de nuestros profesores y alumnos, favoreciendo el uso de los Mapas Conceptuales como un recurso metodológico orientado al aprendizaje significativo y la construcción del conocimiento en escuelas y liceos de Chile.

2 Metodología

El objetivo central de este estudio fue desarrollar un software que permita construir Mapas Conceptuales, basándose en las metodologías de uso y propósitos que aquellos profesores que usan y aplican cotidianamente los mapas conceptuales en sus actividades pedagógicas, han definido como requerimientos para favorecer su uso en la construcción de significados.

El estudio fue desarrollado en tres diferentes etapas: Identificación de los requerimientos, Diseño y desarrollo del software dMC, Evaluación de la Usabilidad, *1.1 Identificación de requerimientos*

1.1.1 Caracterización de la muestra

Para la realización del estudio se seleccionó una muestra intencionada de 15 profesores que tuvieran las siguientes características: un alto nivel de dominio del soporte teórico de los Mapas Conceptuales, que utilizaran Mapas Conceptuales como apoyo al aprendizaje de sus alumnos, y que tuviesen un nivel de usuario avanzado en el uso de TICs como apoyo al aprender. La muestra quedó constituida por profesores de educación primaria y secundaria, de diferentes especialidades como biología, lenguaje y comunicación, contabilidad, física, historia y matemáticas. El 66% de ellos posee estudios de postítulo, un 60% utiliza las TICs como apoyo al aprender varios días a la semana con sus alumnos, se clasifican entre los niveles medio y experto en cuanto al dominio teórico en el tema de Mapas Conceptuales, y los utilizan a lo menos una vez a la semana desde hace tres años como mínimo.

La intencionalidad en la selección de la muestra responde a la necesidad de contar con la visión de quienes desde su acción pedagógica con Mapas Conceptuales y TICs, podían aportar información pertinente a nuestros propósitos de diseño y desarrollo de un software de Mapas Conceptuales para apoyar la práctica pedagógica cotidiana.

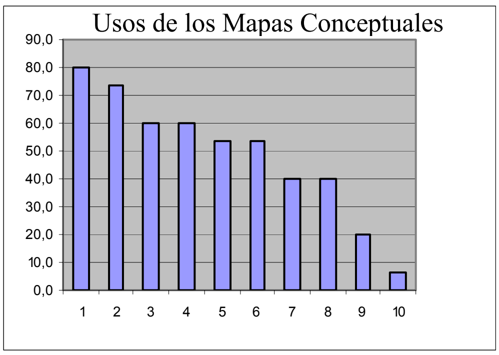
1.1.2 Instrumento

Para obtener los datos e información inicial necesaria sobre la experiencia de estos profesores, se utilizó una encuesta que constaba de cuatro partes: 1. Identificación de las características del profesor y su *expertise* en el área que nos encontrábamos investigando, 2. Determinación de cómo y para qué son utilizados los Mapas Conceptuales por los profesores en el trabajo pedagógico con los alumnos, 3. Indagación sobre su experiencia en el uso de software que permita apoyar actividades de construcción de Mapas Conceptuales y la evaluación que desde la práctica realizan de estas herramientas, 4. Finalmente, consulta sobre los recursos y reportes que debería considerar un software diseñado para construir Mapas Conceptuales con propósitos educativos. La encuesta fue aplicada a través de correo electrónico y los profesores tuvieron un plazo de cuatro días para desarrollarla.

1.1.3 Resultados

Uso metodológico de los Mapas Conceptuales
Todos los profesores manifiestan que abordar la construcción de Mapas Conceptuales con alumnos es un proceso que se realiza a través de pasos o etapas. Al analizar en profundidad la información y datos entregados por los profesores, se evidencia una regularidad en los pasos a seguir para la construcción de Mapas Conceptuales, permitiéndonos sintetizarlos en cinco etapas: 1. Seleccionar y revisar el tema que se presentará a los alumnos, 2. Identificar y clasificar los conceptos relevantes del tema, 3. Jerarquizar y ordenar los conceptos seleccionados, 4. Establecer los conectores y enlaces, y 5. Hacer y rehacer el mapa cuantas veces sea necesario. Adicionalmente, con menos regularidad se manifiestan otras etapas como determinar enlaces cruzados y agregar ejemplos.

Por otra parte, identificamos que los objetivos y propósitos más frecuentes de las actividades en que los profesores utilizan Mapas Conceptuales son: realizar una síntesis final de la materia, organizar información, elaborar un resumen esquemático de lo aprendido, estudiar, identificar los conceptos previos del alumno y evaluar. En menor porcentaje se manifiestan usos como realizar presentaciones de información, introducir un nuevo concepto, extraer significados de textos escritos y negociar significados (ver Figura 1).



1. Realizar una síntesis final de la materia
2. Organizar información
3. Elaborar un resumen esquemático de lo aprendido
4. Estudiar
5. Identificar conceptos previos del alumno
6. Evaluar
7. Realizar presentaciones
8. Introducir un nuevo concepto
9. Extraer significados de textos escritos
10. Negociar significado

Figura 1. Objetivos y propósitos para los cuales son usados los Mapas Conceptuales

Uso de software para la confección de Mapas Conceptuales
A pesar que en la práctica se le presentó al encuestado software orientado a la construcción de Mapas Conceptuales, existe un 40% que señala no conocer este tipo de herramientas, y que para apoyar la construcción de mapas, utilizan herramientas de productividad como procesador de textos MSWord y software de presentación MSPower Point. El 60% restante identifica herramientas como Inspiration y en menor medida, reconocen CmapTools, ConceptDrawMINDMAP y VisiMap, como software orientado a la construcción de Mapas Conceptuales.

Los elementos más valorados como fortalezas de estas herramientas son la interfaz gráfica y lo fácil que puede llegar a ser usarlos, así como también que consideren versiones para diferentes tipos de usuarios. Otros elementos destacados de estas herramientas son: la flexibilidad con que se manipulan y ordenan los conceptos y la posibilidad de realizar diferentes tipos de mapas. En tanto se identifican debilidades de estas herramientas que se sintetizan en: costo elevado para adquirirlas en el establecimiento (la mayoría de ellas), estar desarrolladas en inglés, la ausencia de contenido específico de Mapas Conceptuales a modo de tutorial u otro tipo de ayuda que apoye a los usuarios que desconocen esta técnica, el escaso feedback del software en relación a la confección del mapa, y que en su mayoría son de difícil exportación para incluirlos en otras herramientas y requerimientos de hardware por sobre el estándar.

Software ideal desde la perspectiva de los profesores
Las herramientas y recursos que, según los profesores, debería considerar un software de Mapas Conceptuales implementado para apoyar la actividad pedagógica son:

- Sugerencias metodológicas para el uso pedagógico de los Mapas Conceptuales, tales como ejemplos de actividades, recomendaciones didácticas, ejercicios. Asimismo, se solicita incorporar un espacio tutorial orientado al aprendizaje de la técnica.
- Capacidad de imprimir los mapas y diferentes reportes que el software debería entregar.
- Posibilidad que el profesor agregue comentarios y observaciones a los mapas elaborados por los alumnos.
- Ejemplos de Mapas Conceptuales elaborados por profesores y alumnos en diferentes tópicos y con diferentes propósitos.
- Incorporar elementos gráficos como galería de imágenes y medios, herramientas de dibujos, posibilidad de manejar el color de la tipografía y los enlaces.
- Herramientas que faciliten o apoyen los procesos de evaluación de los Mapas Conceptuales.
- Acceso individualizado de los usuarios que genere un registro histórico de cada uno y les de la opción de compartir con otros sus construcciones.
- Que el profesor pueda visualizar y comparar varios mapas al mismo tiempo, aplicando herramientas de búsqueda de conceptos, superposición de diferentes mapas, estadística de los conceptos y enlaces utilizados por uno o más alumnos.
- Posibilidad de actualizar el software a través de soporte web.

Asimismo, las herramientas y recursos para los alumnos que debería incluir este software son:

- Herramientas flexibles y fáciles de usar para incorporar los elementos propios de un mapa conceptual.
- Posibilidad de imprimir sus mapas y reportes.
- Incluir ejemplos de mapas elaborados en diferentes tópicos y con diferentes propósitos.
- Editar mapas elaborados anteriormente, permitir una construcción progresiva.
- Agregar herramientas gráficas y de medios, herramientas de dibujo.
- Incluir comentarios, observaciones y explicaciones de sus mapas y revisar comentarios y modificaciones realizadas por el profesor.
- Incluir un tutorial que les permita aprender la técnica.

En términos de reportes e información, el software debe proveer al profesor:

- Registros estadísticos de conceptos utilizados, enlaces, niveles en la jerarquía, proposiciones, por alumno y promedios por curso.
- Registros de secuencias o pasos que el alumno siguió en la confección de mapas, estimando el tiempo que duró cada una de ellas, estos registros deberían proveerse por alumno y almacenarse en el historial.
- El historial debe incluir además un registro de todos los mapas elaborados por el alumno.

Los reportes e información para los alumnos que debiera incluir el software son:

- Registros de conceptos, enlaces, proposiciones, utilizados en sus mapas.
- Registro histórico de los mapas que ha construido y los cambios que ha realizado en ellos así como de los comentarios que el profesor ha realizado a sus trabajos.

- Reportes de feedback respecto de la construcción de mapas, por ejemplo a través de pistas que le ayuden a resolver problemas formales en la construcción.

1.2 Diseño y desarrollo del software

A partir de la experiencia desarrollada por los profesores en el uso de software para construir Mapas Conceptuales y de la cantidad de información y datos aportados en términos de requerimientos para un software con este propósito, se optó por desarrollar un software a partir de un modelo basado en prototipos, que acogiera progresivamente los requerimientos de los usuarios y cuyas versiones preliminares fueran constantemente sometidas a su evaluación, proveyendo de feedback desde el momento de la producción. Es así como desarrollamos el software dMC, Diseñador de Mapas Conceptuales, un software que apoya y facilita la construcción de Mapas Conceptuales para fines de aprendizaje en escuelas y liceos.

1.2.1 Implementación del software dMC

El diseñador de Mapas Conceptuales posee diferentes componentes, básicamente organizados según el tipo de usuario que interactúa con el software y las actividades que desea crear (ver Figura 2). Para el ***profesor***, las actividades disponibles son: edición de una galería de imágenes, edición de una galería de conceptos, edición de una galería de textos de conceptos, creación de mapas, edición y lector de mapas. Para el ***alumno***, las actividades disponibles son: creación de mapa de imágenes, creación de mapa de conceptos, creación mapa de texto y completar mapa.

Para la construcción y almacenamiento de mapas se desarrollaron estructuras de datos orientadas al objeto, haciendo así más fácil el desarrollo y la interacción con el software. Los mapas creados son guardados con el nombre del usuario para continuar posteriormente su elaboración si el usuario lo requiere. Los mapas creados por los alumnos pueden ser guardados y exportados como bitmaps para su posterior discusión y evaluación por el profesor (ver Figura 7). Las galerías de imágenes, conceptos y textos son extensibles, agregando archivos a las carpetas correspondientes en la ruta donde la aplicación está instalada. En la Figura 2 se describe el modelo simplificado del software, indicando las interacciones entre los principales agentes intervinentes.

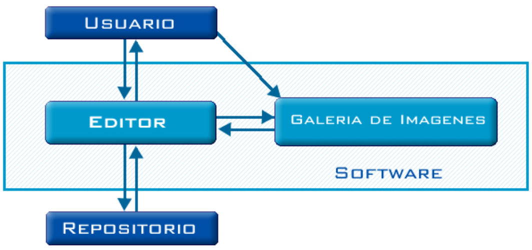


Figura 2. Modelo de funcionamiento de dMC

El primer agente representa al tipo de usuario que interactúa en el sistema, si es profesor, las funcionalidades disponibles son principalmente para modificar o agregar imágenes y conceptos en la galería disponible. El editor es el encargado de crear conceptos en el mapa, crear las relaciones entre ellos y disponer de todas la funciones generales (abrir, guardar, imprimir). Además, mantiene las variables que caracterizan a cada mapa: número de nodos, número de enlaces simples, número de enlaces cruzados y relaciones entre conceptos. La galería de imágenes contiene los objetos (conceptos) que el usuario tiene a disposición para crear mapas, los que son importados automáticamente al iniciar la aplicación, generando categorías de acuerdo al nombre de las carpetas. El repositorio mantiene los mapas creados según el usuario que los ha creado. Al momento de ingresar a la aplicación y consultar el tipo y nombre de usuario, se cargan automáticamente los mapas creados con la opción de modificación.

dMC fue desarrollado con Macromedia Director 8.5 y puede ser ejecutado en PCs con sistema operativo Windows 9X, Pentium 333 Mhz, 32 MB de memoria RAM y DD de 20 MB.

1.2.2 Interfaces

La interfaz principal permite seleccionar el tipo de mapa con que se desea trabajar a través de un menú desplegable (ver Figura 3). Las opciones son: mapa de imagen, mapa de concepto y mapa de texto. Asimismo, presenta en pantalla todas las posibilidades de actividades para el profesor y actividades para los alumnos. Para crear un mapa, inicialmente se deben construir categorías en las cuales se editen los contenidos con los que se trabajarán. Los contenidos pueden ser imágenes, conceptos o textos, dependiendo del tipo de mapa que se desee crear. Estos contenidos son clasificados en las categorías que se van construyendo de acuerdo a la organización de contenidos, temas o unidades que se traten en la clase.

La Figura 4 representa la interfaz del profesor para la edición e importación de imágenes para trabajar con mapas gráficos. Desde aquí el profesor o alumno pueden seleccionar imágenes preexistentes e importar nuevas imágenes para agregarlas a la galería y clasificarlas en sus categorías. Cada imagen tiene un concepto asociado, que puede ser editado de acuerdo a las necesidades de la actividad. La Figura 5 muestra la interfaz para que profesores o alumnos modifiquen, agreguen o eliminen conceptos, clasificándolos en una categoría. La Figura 6 representa la interfaz que permite incorporar textos escritos. Desde aquí profesores o alumnos pueden importar textos o escribirlos directamente, clasificándolos en alguna categoría y luego seleccionar los conceptos relevantes que se agregarán automáticamente en la categoría donde fue clasificado el texto.

Figura 3. Interfaz de selección de tipo de usuario y actividad

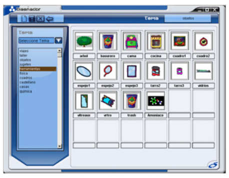


Figura 4. Sección de edición de la galería de imágenes

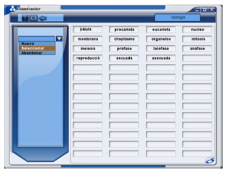


Figura 5. Sección de edición de la galería de conceptos

Figura 6. Sección de edición de la galería de textos

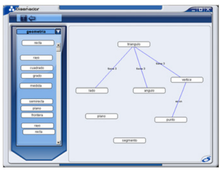


Figura 7. Creador de mapas de Conceptos

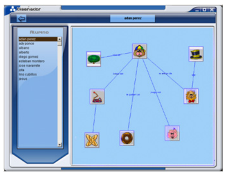


Figura 8. Lector de mapas

dMC permite construir mapas textuales y gráficos, utilizando conceptos e imágenes que se han guardado en las diferentes categorías. Para crear mapas se selecciona la categoría y el tipo de mapa, de esta forma se presenta una interfaz que dispone de las herramientas para su construcción (ver Figura 7).

Los conceptos se toman y ubican libremente en el espacio de creación. Las líneas de los enlaces se generan al hacer un clic con el botón alternativo del ratón en uno de los conceptos y arrastrando hasta el otro concepto. Finalmente, para escribir la palabra enlace se hace un clic sobre la línea. La Figura 8 representa la interfaz que permite visualizar los mapas creados por los alumnos o profesores. Todos los mapas son almacenados de acuerdo a la clasificación del tema y diferenciados para cada uno de los usuarios.

Desde el modo visualizar, profesores y alumnos puede realizar observaciones, insertar notas, destacar con color alguna parte del mapa y hacer cambios. Estos cambios se guardan como una nueva versión del mapa, permitiendo generar un registro histórico de las versiones y los cambios realizados en el tiempo.

1.3 Evaluación de usabilidad del software dMC

1.3.1 Metodología

El estudio consistió en dos tipos de evaluación de la usabilidad de dMC. Una evaluación del usuario final que consideró un cuestionario de aceptación y un focus group, y una evaluación heurística realizada por usuarios expertos. La evaluación constó básicamente de 4 etapas: introducción, exploración del software, aplicación de cuestionarios de aceptación y Focus Group. En la etapa de introducción se les explicó a los profesores el objetivo de la investigación y el procedimiento de trabajo. En la etapa de exploración el profesor debía interactuar con el software revisando y descubriendo todas las funcionalidades disponibles, con el objetivo de crear y manipular Mapas Conceptuales. Este proceso duró aproximadamente 30 minutos. Posteriormente, se aplicaron pautas de evaluación de usabilidad definidas para la investigación. En la última etapa hubo una conversación en relación al software, obteniendo como resultado el feedback de los usuarios representado en ventajas y desventajas. Finalmente, confeccionamos un listado de atributos para realizar un rediseño definitivo de dMC. Adicionalmente, tres expertos evaluaron la usabilidad de dMC utilizando para ello una pauta de evaluación heurística (Sánchez 2001).

1.3.2 Muestra

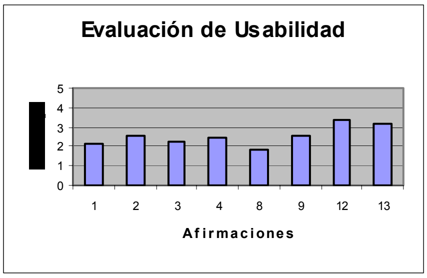
La muestra estuvo constituida por 10 profesores que trabajan con Mapas Conceptuales en sus prácticas pedagógicas en diferentes niveles de escolaridad. El 40 % de la muestra tiene algún postgrado en el área de informática educativa. Además, participaron 3 expertos en usabilidad para la evaluación heurística. Estas son personas con formación técnica de ingeniería, con experiencia en la evaluación de la usabilidad de las interfaces.

1.3.3 Instrumentos

Para los usuarios finales el instrumento utilizado fue un cuestionario de evaluación de la usabilidad desarrollada por Sánchez (2001). Esta evaluación está basada en la medición de diferentes atributos medidos con una escala tipo Likert. El usuario expresa su grado de satisfacción con los criterios presentados, 1. Muy de Acuerdo, 2. De acuerdo, 3. Neutro, 4. Desacuerdo y 5. Muy en Desacuerdo. Para los usuarios expertos se utilizó la pauta de evaluación heurística (Sánchez, 2001), basada en una inspección sistemática de la interfaz de dMC. Esta pauta es un cuestionario extenso y detallado que permite a través de una inspección profunda, evaluar la usabilidad del software considerando doce heurísticas, postuladas por Nielsen (1993) y Schneiderman (1998).

1.3.4 Resultados

Los resultados de ambas evaluaciones se representan en las Figuras 9 y 10. En la evaluación de usabilidad para usuarios finales, de 13 afirmaciones del instrumento se consideraron 8 para esta evaluación (ver Figura 9).

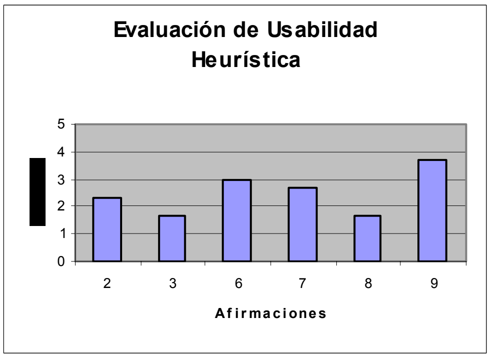


1	Visibilidad del estado del software
2	Relación entre software y mundo real
3	Control del usuario y libertad
4	Consistencia y estándares
8	Estética y diseño minimalista
9	Reconocimiento
12	El software tiene todas las funcionalidades esperadas
13	El software tiene todas las capacidades esperadas

Figura 9. Resultados de la evaluación de usabilidad por usuarios finales

En general, la mayoría de las afirmaciones sobre distintos aspectos de la interfaz obtiene buena aceptación por parte de los profesores usuarios (ver Figura 9). Los aspectos con mejor aceptación son la *estética y diseño minimalista*, *la visibilidad del estado del software*, y *control y libertad del usuario*. Adicionalmente, un 70% califica como "Buenas" las interfaces del software.

La evaluación de usabilidad por expertos consideró 12 heurísticas de las cuales se analizan 6 de ellas, consideradas relevantes para los propósitos del estudio (ver Figura 10).



2	Relación entre software y mundo real
3	Control del usuario y libertad
6	Reconocer en lugar de recordar
7	Facilidad de acceso a los lugares del software
8	Estética y diseño minimalista
9	Reconocimiento, diagnóstico y recuperación de errores

Figura 10. Resultados de evaluación de usabilidad heurística

Los expertos consideran que la mayoría de las heurísticas de interfaces se cumplen en el software. Las heurísticas con mejor aceptación son: *control y libertad del usuario*, que indica las posibilidades que el software entrega al usuario en su interacción con el sistema; *estética y diseño minimalista*, que considera aspectos como relevancia y organización del contenido, y funcionalidad y distribución de la interfaz; *relación entre software y mundo real*, indicando la claridad del lenguaje, entendimiento de los conceptos utilizados, familiaridad del lenguaje y significado de la iconografía. En tanto la afirmación de menor aceptación es el *reconocimiento,* *diagnóstico y recuperación de errores*, considerando el feedback que el software provee al usuario para que evite errores y rectifique en caso de cometerlos.

3 Discusión y proyecciones del estudio

Este estudio tuvo por finalidad diseñar un software para diseñar Mapas Conceptuales para uso de profesores del sistema educacional chileno. Para ello, se elaboró una metodología que permitiese diseñar dicho diseñador con ellos y para ellos. La idea fue diseñar y rediseñar el producto de manera que se ajuste exactamente a las necesidades específicas del usuario. Como resultado, hemos mostrado una metodología de diseño y rediseño, lo cual nos ha permitido diseñar dMC y a partir de éste elaboraremos un producto final que será utilizado en las escuelas y liceos de Chile. Estamos implementando la versión final del software luego del rediseño basado en la metodología propuesta y los resultados de la evaluación de usabilidad, incorporando otras nuevas funcionalidades.

En el intertanto, la aplicación sistemática de dMC nos permitirá observar in situ el uso del software en actividades de aprendizaje, la interacción que se produce entre los usuarios, la forma cómo facilita la construcción de Mapas Conceptuales, y qué objetivos pedagógicos alcanzan los alumnos. Recogeremos una inquietud de los profesores de integrar a dMC una herramienta que apoye la evaluación de los Mapas Conceptuales, sobre la base de un sistema experto que permita modelar la aplicación de los Mapas Conceptuales en actividades de aprendizaje para apoyar la evaluación. Con este producto final, planeamos realizar una nueva evaluación de usabilidad durante este año, para iniciar su uso sistemático en escuelas y liceos a contar de marzo del 2005, apoyando así la construcción de significados de aprendices chilenos.

4 Agradecimientos

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USES OF CONCEPT MAPPING IN TEACHER EDUCATION IN MATHEMATICS

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Abstract A case study of the concept maps of two pre-service teachers illustrates the potential of concept mapping to the teacher educator. The maps reveal much about whether future teachers grasp the nature of mathematics as a conceptual system, understand the conceptual content of mathematical procedures, and possess the requisite pedagogical content knowledge to mediate such understandings to future learners. The map of one of the two teachers reveals that she possesses these understandings. The map of the other shows a formalistic understanding of mathematics. Concept mapping also functions as an epistemological heuristic for pre- and in-service teachers.

1 Case Study

Despite the emphasis on conceptual understanding that characterizes the reform standards of the National Council of Teachers of Mathematics, concept mapping in mathematics has been underutilized in the US. This is unfortunate, since it has the potential to begin to counteract the superficial treatment of concepts occasioned by the failure to develop a coherent curriculum that identifies essential concepts and probes them in sufficient depth. In addition, reform mathematics curricula have all but abandoned the teaching of algorithms, preferring to consign computation to calculators instead (Morrow & Kenney, 1998). This practice has not only been widely criticized (Hu, 1999; Schmittau, in press), but, has in fact, played a major role in fueling the US "math wars". At the root of this false dichotomy between mathematical procedures and mathematics concepts is the notion that algorithms can only be taught mechanically, as they often were in the past, and are therefore, incompatible with the teaching of concepts. Algorithms, however, are fully conceptual cultural historical products and should be taught as such. Concept mapping can serve as a useful tool to enable the linking of algorithms with their conceptual content.

The following case study of the concept maps of two pre-service teachers illustrates this point, and provides an example of the manner in which a concept map can alert the teacher educator to whether or not students are understanding mathematics as a conceptual system (in which procedures are fully integrated), or grasping it at the level of mere formalism (Schmittau, 2003). Both students drew maps of their understanding of the concept of multiplication, subsequent to extensive class discussion of the concept. Since the maps were quite large, space considerations limit presentation to small sections of each.

In Figure 1 A, a section of Katie's map reveals her understanding of what multiplication *is,* viz., "a change in units in order to take an indirect measure" (cf. Davydov, 1992). Shawn, however, sees multiplication as an "operation which is composed of" an "operator" and "operands" (Figure 1B). Katie's definition can be meaningfully taught to children in the early elementary school years (Davydov, 1992), while Shawn's would make very little sense to students prior to college mathematics.

Katie's definition reflects the development of multiplication from the need to take a measurement or count of a quantity of objects or units sufficiently numerous to render a direct count tedious and subject to error. In such a circumstance, it is advantageous to construct a larger unit (or multiple) of the unit of interest, and use it to take an indirect count. This is done in the case of the area of a rectangle, for example, when the number of unit squares in a row are counted, and then the number of rows are counted in order to indirectly obtain the area as the number of square units. Such an understanding of multiplication underlies the algorithm for obtaining the product of multi-digit numbers. It does, however, require that the products of single digit numbers (multiplication "facts") be committed to memory. It is not sufficient that the calculator can call up these "facts"; they must be stored in the human memory if they are to be recognized in subsequent mathematical studies in the myriad of conceptual interrelationships into which they enter. Katie refers to these in her concept map, indicating that their commitment to memory is important for mathematical understanding, and should not be by-passed as is often now occurring in the wake of the reform movement. All of these points were emphasized during our extensive class discussions of the concept of multiplication and the various numerical domains in which it is defined. During these we noted the inadequacy of the "repeated addition" definition that is ubiquitous in US textbooks (Schmittau, 2003). Accordingly, neither Katie nor Shawn invoked this notion in their concept maps of multiplication.

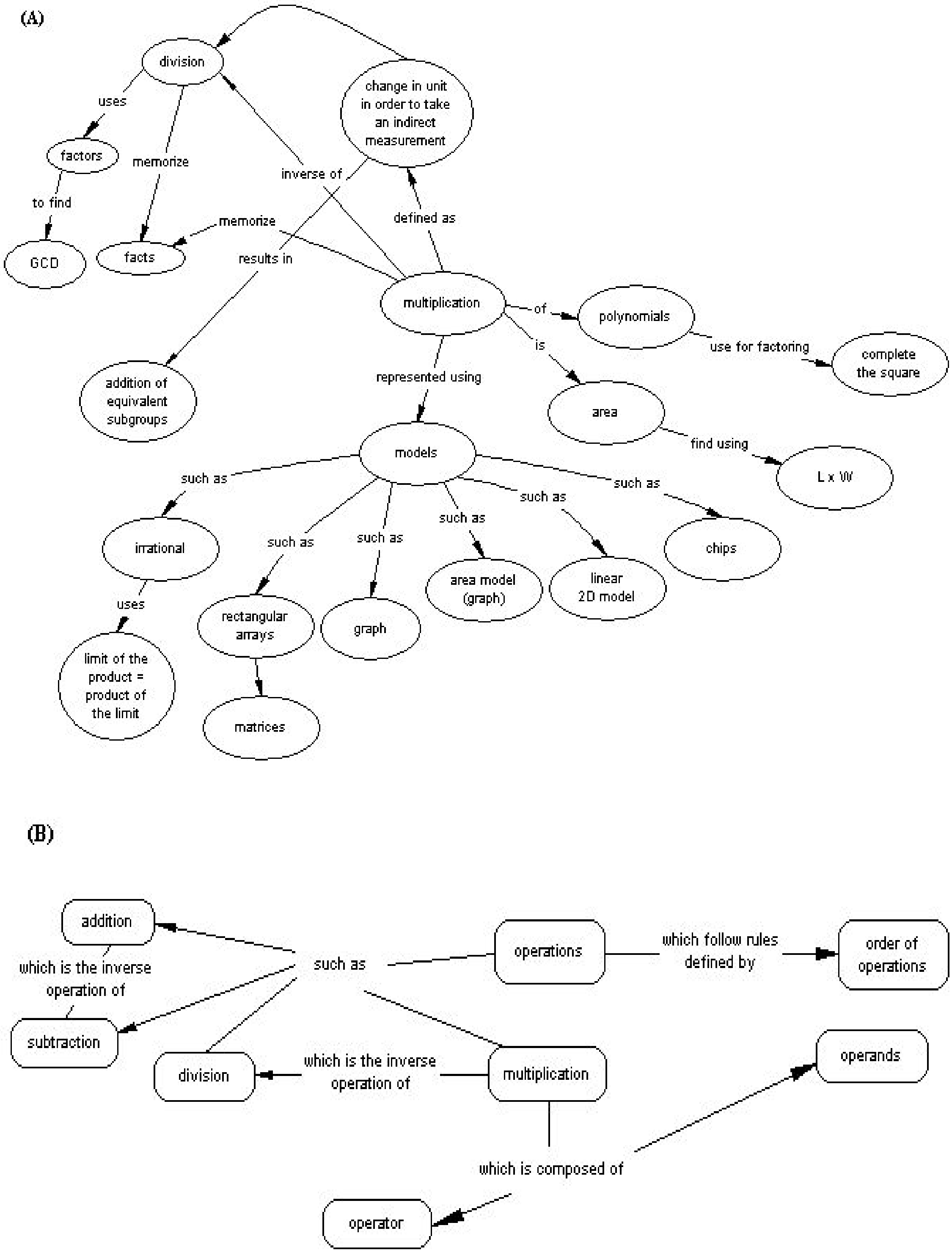


Figure 1. Katie's (A) and Shawn's (B) maps of the concept of multiplication.

In Figure 2, a portion of Katie's map reflects the centrality of the concept of area to her understanding of multiplication. In the case of rectangular area, the unit changes from a unit square to a row of such squares, which can then be counted to obtain the area in square units. Katie also presents area models for the conversion of a sum of terms (polynomial) to a product (factoring) following the methods of Al-Khowarizmi (Karpinski, 1915). Such area models are the conceptual foundation for the completion of the square. The upper model for the solution of the quadratic equation "$x^2 + 10x = 39$" shows Al-Khowarizmi's method, while the lower model displays the solution using algebra tiles. In his development of algebra 1000 years ago, Al-Khowarizmi solved this equation by first drawing a square (having dimensions x by x), then dividing 10 by 4, and using the result to add a rectangle of dimensions "x" by 2.5 to each side of the square. There were as yet no algebraic symbols, but since it is cumbersome to use word labels for variables, in my presentation to Katie and Shawn's class, I labeled the length of these four rectangles "x". Al-Khowarizmi then literally completed the square (the new larger square, that is) by adding the four small squares in each corner. Each of these had an area of 2.5 x 2.5 = 6.25, and since there were four of them, their total area was 25 square units. Now the original equation (again we are using symbols that Al-Khowarizmi lacked) becomes $x^2 + 10x + 25 = 39 + 25 = 64$. Since the length of a side of the square is x + 5 and the area of the square is 64, the square has dimensions 8 by 8, and x + 5 = 8. Hence, x is 3. (Al-Khowarizmi's geometric method did not permit negative solutions.)

Katie's lower model shows an algebra tile model for the same problem. Algebra tiles are a modern manipulative designed to geometrically model polynomials. Although the ten "x by 1" rods cannot be broken (to obtain rods having a dimension of 2.5 as in Al-Khowarizmi's solution), they can be arranged to produce a new larger square by placing five of them along the side and five along the bottom of the x by x square and completing the new square with 25 unit squares.

Katie's inclusion of these models in her map is important for several reasons. First, the map reveals area as the central antecedent concept necessary for an understanding of factoring. Many secondary students fail to grasp factoring despite the use of algebra tiles, and teachers typically do not understand why a model that is so transparent to them is not equally so for their students. If teachers realize that area is insufficiently understood by many students (Schmittau, 2003), they will understand why area models sometimes fall short of their anticipated effect. Second, Katie's map reveals a knowledge on her part of the cultural historical development of the solution of the quadratic equation by factoring, as well as its current rendering by the use of a popular manipulative. Her map reveals that she has internalized from the class presentations, the relevant content and pedagogical content knowledge necessary to teach this concept meaningfully.

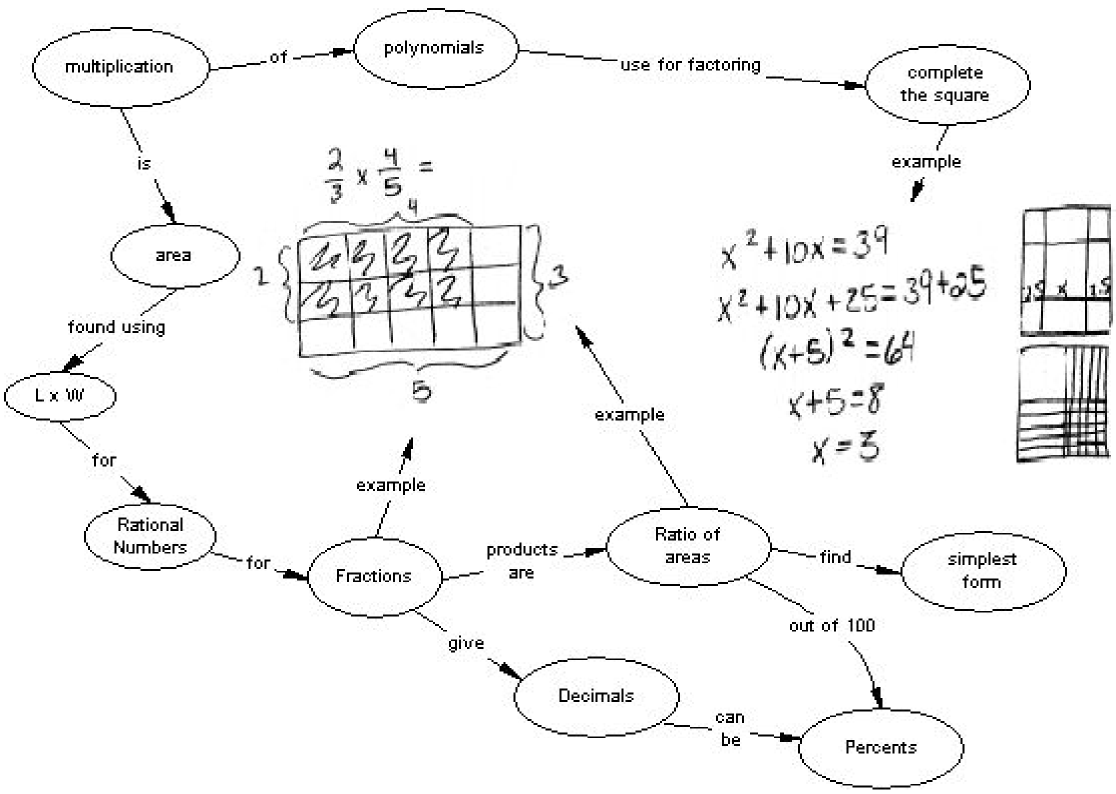


Figure 2. Katie's map showing the historic role of the concept of area in the development of algebra and the factoring of polynomials, and the concept of area underlying the algorithm for the multiplication of fractions.

Some teachers resist the use of algebra tiles, believing that a solution method that is purely "algebraic" (i.e., symbolic), is just as effective. However, the fact that Al-Khowarizmi tested his invented algebraic methods against geometric models and that geometric models were used up to the nineteenth century, should caution against the tendency to omit this important step in concept development. Further, Al-Khowarizmi invented this method one thousand years ago, some 500 years before the creation of algebraic symbols. So immediately engaging students at the level of symbolic expression omits from their ontogenetic experience the equivalent of hundreds of years in the phylogenetic development of this concept. Such an approach can scarcely be considered a recipe for adequate conceptual understanding.

If we explore this portion of Katie's map further (Figure 2), we see an area model for the multiplication of fractions also, in which the algorithm for the product of two fractions is identified by Katie as a "ratio of areas". Katie now understands what virtually none of my graduate students in mathematics understand prior to our class discussions, viz., that the reason why the algorithm for the product of two fractions "works", is because the product of the numerators and the product of the denominators are *areas* whose ratio is the product of the fractions. In the example used by Katie, viz., "2/3 x 4/5", the shaded area of the rectangle represents the product of the numerators "2 x 4", while the area of the larger rectangle is the product of the denominators "3 x 5". Their ratio, 8/15, is four-fifths of two-thirds, the product of the two fractions.

Shawn (Figure 3) states simply that "integer fractions" … "have the multiplication formula a/b x c/d = ab/cd which is a ratio of area". Without further elaboration or a model representation, it is difficult to discern from his map alone whether he grasps the precise nature of this ratio. This propositional acknowledgement alone, however, is more than is commonly perceived by the typical pre-service or in-service teacher.

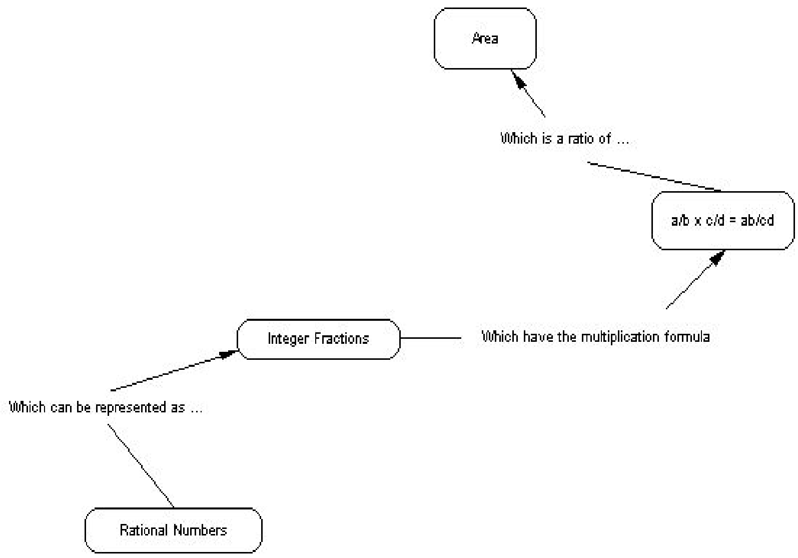


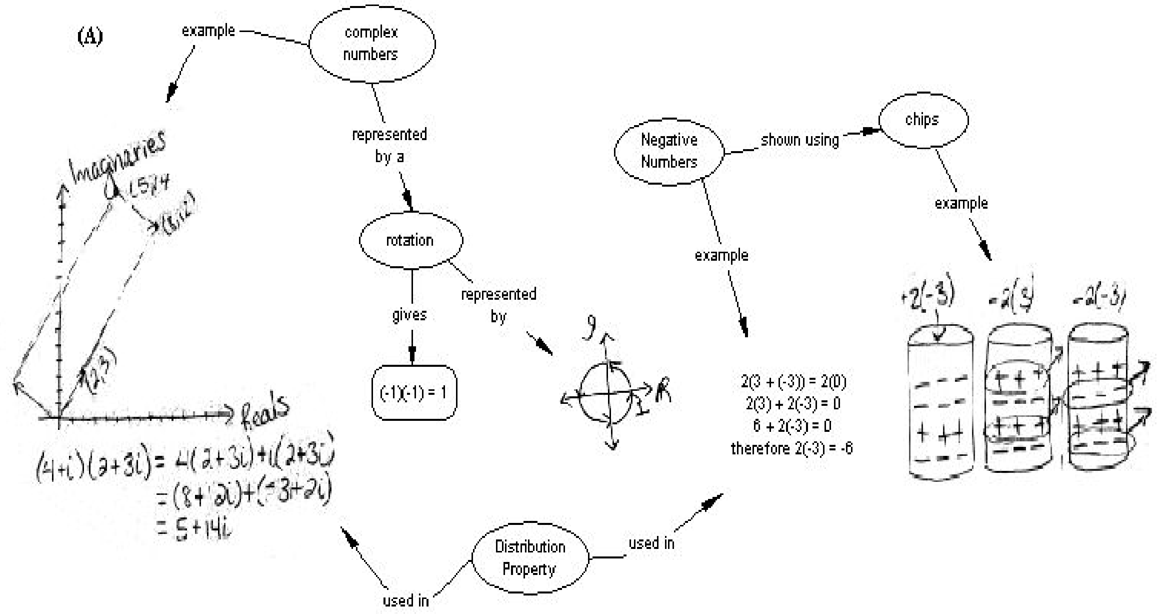
Figure 3. Shawn's map showing a formalistic understanding of fraction multiplication.

Finally, the current reform movement in mathematics often advocates that teaching go no further than the use of manipulatives, and then allow students to "construct" their own algorithms (Morrow & Kenney, 1998). There is, however, no certainty that such student constructed algorithms will be correct. This does not seem to matter to the reformers, who appear unable to connect the powerful culturally and historically constructed algorithms with their conceptual content. Their answer is to abandon the teaching of such general methods in favor of dealing only with "concepts", a practice that relegates procedural knowledge further to the rote end of the meaningful-rote learning continuum (Novak & Gowan, 1984), reducing it to little more than a memorized sequence of calculator keys. Katie's map, however, reveals that she is aware of the development of this concept in the historical progression of mathematical knowledge, and furthermore, possesses the pedagogical content knowledge necessary to teach it effectively to students.

Another aspect of multiplication students find incomprehensible concerns the product of two negative numbers. In Figure 4A, Katie's map indicates that multiplication of negative numbers can be modeled using chips to represent positive and negative charges. Such a model makes use of Ausubel's concept of an advance organizer, which is often necessary because of the early grades (frequently 5^{th} or 6^{th}) at which this topic is introduced. Here, the notion of charged particles serves this function. In the model showing containers of charged particles, Katie first shows +2(-3). Beginning with 3 positive and 3 negative charges in the container on the left (for a net charge of zero), two groups consisting of 3 negative charges in each, are added, resulting in a net charge of –6. From the middle container (starting with 6 positive and 6 negative charges), two groups of 3 positive charges are removed, representing –2(+3) and leaving a net charge of -6. From the container on the right (again starting with 6 positive and 6 negative charges), two groups of 3 negative charges are removed, leaving a net charge of +6. Such a use of an advance organizer is imperative, I argue in our class discussions, because the conceptual integration of the product of two negatives is to be found in the system of complex numbers, which is not studied until high school, long after this topic has been taught.

Accordingly, Katie's map shows a real understanding of the conceptual connections I presented to her class, linking the product of two negatives to the complex number system. Her map displays a linkage from negative numbers to the product "(-1)(-1) = 1" which is linked to multiplication of "complex numbers" and "represented by a rotation" shown in the complex plane. This is the actual inception of the concept of multiplication by a negative number, and Katie's representation of (4 + i)(2 + 3i) in the complex plane together with her assertion that the "distributive property" is "used in" obtaining this product, suggests an understanding that multiplication by the scalar quantity "4" repeats the vector (2,3) four times, quadrupling its norm (length) and resulting in the vector (8,12). Multiplication of (2,3) by "i", however, in a decided break with the meaning of multiplication for real numbers, produces a 90^{o} counterclockwise rotation of this vector, resulting in the vector (-3,2). In class I showed students that the vector (1,0) when multiplied by "i" rotates to the vector (0,1). Multiplying by "i" again results in the vector (-1,0). Hence, the fact that (-1)(-1) = 1 is due to the fact that –1 multiplied by itself reflects two further 90° counterclockwise rotations, i.e., the vector (-1,0) is rotated 180 degrees to (1,0). Katie's model shows four 90 degree counterclockwise rotations to produce the real number "1", which she states is "(-1)(-1)". This, together with linkages to the graph of the product of two complex numbers obtained using the "distributive" property, connected to "complex number" that are "represented by a rotation" modeled in the complex plane, suggests that she has internalized what was taught in my graduate course, and has both the relevant content knowledge and pedagogical content knowledge to teach this concept with meaning. A teacher who possesses these understandings may be expected to point out the connection to multiplication of negative numbers when multiplication of complex numbers is taught. None of my graduate students in mathematics have ever made this connection. They learn it for the first time in my graduate course.

Shawn's map deals with this topic very minimally, without models. His map states that for complex numbers "multiplication is defined by… (a+bi)(c+di) = (ac – bd) + (cb + ad)i". This section of his map is unconnected to the section dealing with "negative numbers" (Figure 4B). Here he states that "When a and b are both negative… a x b = (-a) – (-a) - …", that is, "-a subtracted from itself b times". If that is the case, then (-3)(-2) = (-3) – (-3) = 0, rather than +6. Hence, despite the fact that several meaningful ways of modeling this concept were presented during our class discussions, Shawn's map suggests that he views multiplication of two negatives as repeated subtraction, which is an inaccurate conceptualization.



(B)

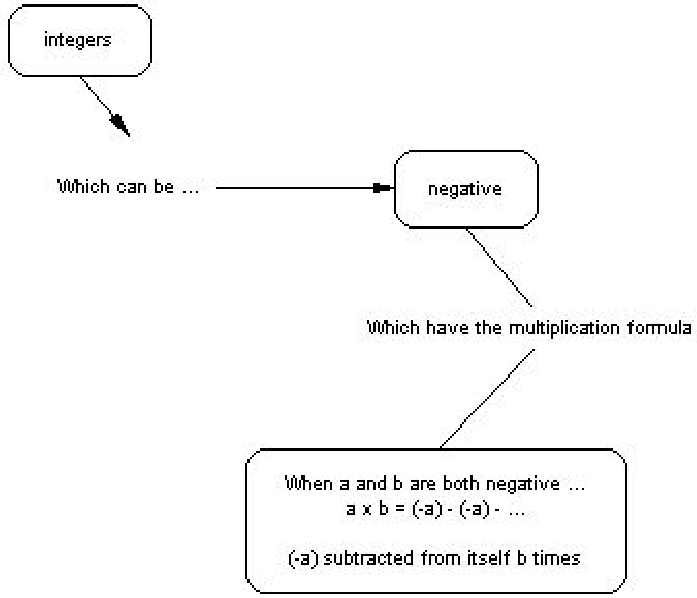


Figure 4. Katie's (A) and Shawn's (B) differing understandings of the multiplication of two negatives.

Shawn and Katie were both present in the same classes in which I taught the conceptual content of this concept that is reflected in Katie's map above. However, the evidence from their maps is that one internalized the concept in its systemic interconnections, while the other continued to see it through a formalistic lens. Katie's map gives evidence that she possesses the requisite conceptual understanding, and historical and pedagogical content knowledge, to mediate the concept of multiplication meaningfully to students, without separating its so-called "procedural" from its "conceptual" content. Indeed, it appears that she can move rather seamlessly between the two. Shawn's map, in its entirety, has considerable extension, encompassing multiplication of matrices, determinants, and the cross products of vectors. But the connections are consistently formalist and give no evidence that his teaching will go beyond a formalistic approach. Both students are nearing completion of the masters' degree, but their maps reveal very different understandings of this fundamental concept.

2 Epistemological Value

While Ausubelian theory emphasizes the conceptual connections that are requisite for meaningful learning (Novak & Gowin, 1984), Vygotskian theory points to the need to unfold the historically developed conceptual content from its encapsulation in symbolic expression in order to pedagogically mediate the full restructuring of the concept (Davydov, 1990). In the examples above, the concept maps produced were made subsequent to class discussions and presentations in which I shared my own conceptual and historical analyses of multiplication with masters' level students preparing to be high school teachers. I typically require that doctoral students conduct such analyses on their own and frame pedagogical recommendations for the improvement of instruction based upon their findings. James Vagliardo's analysis of the concept of logarithm is illustrative of the role of concept mapping in this process (cf. his conference contribution).

In addition, in my work as lead mathematics educator in the Teacher Leadership Quality Partnership in New York state, I use concept mapping to reveal to in-service teachers why it is imperative that they teach topics not contained in their textbooks or the state mathematics curriculum. In mapping mathematical concepts taught in middle school and searching for their conceptual roots, it becomes clear that the concept of bases, for example, is a central antecedent concept with the power to render more effectively the meaning of such concepts as decimals, fractions, and polynomials. But the concept of bases cannot be attained by studying base ten (Vygotsky, 1986); for adequate conceptualization of such a superordinate concept, the study of multiple bases is required. The folly of superficially covering many topics is simultaneously revealed; only by establishing a conceptual base of concepts central to the future development of mathematics, can students begin to grasp the nature of mathematics as a conceptual system. Yet fifteen years into the reform movement, US curricula continue to cover too many topics each year, to repeat the same topics year after year, and with little increase in depth (Schmidt, Houang, & Cogan, 2002). It would seem that the reform movement in mathematics could benefit from the pedagogical potential of concept mapping.

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AMBIENTES DE APRENDIZAJE BASADOS EN MAPAS CONCEPTUALES HIPERMEDIALES

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Resumen: Capacidades tales como razonamiento, comprensión de significado, entendimiento son potencialidades que no evolucionan espontáneamente, sino que deben ser desarrolladas especialmente por cada individuo. Sumado a esto, existe la necesidad de realizar una formación continua, viéndose obligado a abordar grandes volúmenes de información que cambian rápidamente y que deben poder seleccionarse y procesarse en corto tiempo. Para ello es importante lograr que los aprendizajes que se realizan sean significativos y que en la educación formal se trabaje especialmente sobre el meta-aprendizaje y el meta-conocimiento. Se presentan en este trabajo los Ambientes de Aprendizaje MCH, basados en una poderosa herramienta visual denominada *Mapas Conceptuales Hipermediales* (MCH), como así también, conclusiones obtenidas en experiencias de campo. Son el resultado de estudios realizados en el Laboratorio de Investigación y Desarrollo en Informática y Educación (LIDInE) del Departamento de Ciencias e Ingeniería de la Computación de la Universidad Nacional del Sur (Argentina). Las investigaciones que se realizan en este laboratorio se centran en modelos de aprendizaje constructivistas y en la incorporación de la tecnología computacional como medio colaborador en los procesos de enseñanza y de aprendizaje, en tanto ésta esté identificada con el desarrollo de capacidades de pensamiento o con mecanismos aptos para la representación de las ideas.

1 Introducción

Las capacidades humanas de pensamiento, comprensión, entendimiento, son potencialidades que no evolucionan espontáneamente sino que deben ser desarrolladas especialmente. El tiempo y forma de trabajo en tal sentido es determinante en el grado de evolución que puede alcanzar un individuo. Es importante destacar que almacenar información no implica comprenderla, tener la capacidad de relacionarla correctamente con información previamente adquirida o estar en condiciones de aplicarla en forma adecuada en las distintas circunstancias que así se requiera. Para que ello ocurra, los aprendizajes que se realizan deben ser verdaderamente significativos, es decir deben ser "…procesos de desarrollo de estructuras cognitivas, donde se identifica conocer como interpretación del significado" (Ausubel, 1978). Es indudable que todo buen docente se esmera para que sus alumnos desarrollen de la mejor manera todas sus potencialidades. Para ello recurre a distintas estrategias de aprendizaje, orienta el trabajo del alumno estimulando su autonomía, su autoestima y la construcción de estructuras mentales, de ser posible y si corresponde, de mayor nivel de abstracción. Se esmera por lograr que la nueva información se incorpore adecuadamente con las estructuras significativas existentes en el aprendiz, relacionándose en forma semánticamente correcta con los conocimientos adquiridos previamente. Se ha comprobado que el aprendizaje significativo es más resistente al olvido, porque no se encuentra aislado sino integrado dentro del conjunto jerárquico que representa una determinada área temática. Además, "…cuanto mayor sea la "significatividad" del aprendizaje realizado, tanto mayor será también su funcionalidad" (Coll, 1989). En el aprendizaje significativo, lo fundamental es lograr la relación de los nuevos conocimientos con los conocimientos ya existentes. Este proceso de aprendizaje es *activo*, ya que depende de la predisposición del receptor, y *personal*, pues la asimilación que se logre está en función del grado en que se hayan desarrollado los conceptos relevantes en la estructura cognitiva.

¿Cómo llevar a la práctica estas propuestas teóricas? ¿Cómo resolverlo en el aula? Según Novak el uso de los mapas conceptuales (MC) apunta al logro de estos objetivos. Para los integrantes de nuestro grupo de investigación esta propuesta puede verse potenciada, enriquecida y llevada a la práctica con más facilidad y mayor grado de interés si se trabaja con MCH. Novak define los MC como "... un recurso esquemático para representar un conjunto de conceptos incluidos en estructuras de proposiciones" y como "... un recurso esquemático para representar un conjunto de significados conceptuales". Además un MC puede constituir una "estrategia de aprendizaje" y un "método para ayudar a estudiantes y educadores a captar el significado de los temas de estudio" (Novak, 1984). En la educación formal, la elaboración de estos mapas puede utilizarse no sólo como una técnica de estudio, sino que también es de gran valor para que el docente pueda evaluar los conocimientos adquiridos por los estudiantes sobre un tema determinado; se desarrollará más adelante este punto. Se ha podido observar que si bien no aparecen dificultades con el aprendizaje de esta técnica, no resulta una tarea trivial obtener un MC semánticamente correcto, requiere de sucesivos refinamientos. Esto último y la tarea de interconexión de mapas son operativamente complicadas cuando se trabaja con elementos tradicionales, especialmente cuando el número de nodos es elevado y cuando aparecen referencias cruzadas.

2 Sobre los Mapas Conceptuales Hipermediales

Los mapas conceptuales hipermediales (MCH) constituyen una valiosa herramienta para ayudar a los alumnos a lograr aprendizajes significativos. Mantienen toda la riqueza educativa de los MC de Novak potenciada con los beneficios que brinda la tecnología hipermedial (Señas, 1996). Un MCH es un MC que hace uso de los recursos hipermediales como herramientas efectivas y atractivas para su elaboración, mantenimiento y aplicación. Está caracterizado por:

- En un MCH cada nodo de la hipermedia, denominado vista, es una colección de conceptos relacionados entre sí por palabras enlace.
- Se distinguen dos tipos de conceptos: los propios de la vista y los importados a la misma. Los primeros corresponden a aquellos que constituyen inicialmente la vista y los segundos son los que se toman desde otra para poder así establecer relaciones entre conceptos de distintas vistas.
- Las relaciones entre conceptos de una misma vista se denominan relaciones internas y las relaciones entre conceptos de distintas vistas se denominan relaciones externas.
- Se dice que un concepto C perteneciente a una Vista1 explota en otra Vista2 cuando dicho concepto C se desarrolla en la Vista2. Es decir C constituye el nodo raíz del MC desarrollado en Vista2. En este caso se dice que el MC representado en la Vista2 es un submapa del correspondiente a la Vista1.
- Gráficamente los conceptos propios se representan mediante botones elípticos rotulados o elipses rotuladas (según si explotan o no en otra vista), los conceptos importados por rectángulos rotulados con el nombre de dicho concepto y las relaciones (internas o externas) por arcos etiquetados con una palabra enlace. Para representar las relaciones externas se establece un arco etiquetado entre el concepto propio y el concepto importado. Dicha relación debe figurar en ambas vistas.
- Cada vista se identifica con un nombre, (el del concepto propio más abarcativo de dicha vista) y con un color que es usado en todas las elipses que representan los conceptos propios. Los conceptos importados mantienen el color de la vista donde fueron definidos originalmente.
- Se dice que un concepto C perteneciente a una $Vista_1$ explota en otra $Vista_2$ cuando dicho concepto C se desarrolla en la $Vista_2$. Es decir C constituye el nodo raíz del MC desarrollado en $Vista_2$. En este caso se dice que el MC representado en la $Vista_2$ es un *submapa* del correspondiente a la $Vista_1$.
- La elipse que representa un concepto propio que explota en otra vista es un botón que posibilita el acceso directo a esa vista. El rectángulo que representa un concepto importado C es un botón que permite acceder directamente a la vista donde C está definido como propio.
- Un concepto C se dice terminal cuando no es un botón, es decir cuando su representación gráfica es una elipse rotulada.
- Distintas apariencias (gráfico, sonido, animación, esquema, fotografía) se pueden asociar a un concepto terminal. Todo concepto puede tener asociada una apariencia ya que siempre existirá una vista del MCH donde dicho concepto esté definido como terminal. Dicha apariencia debe permanecer oculta detrás de la elipse rotulada que representan el concepto terminal y aparecerá sólo a demanda del lector del mapa.

La incorporación de tecnología hipermedial presenta algunas ventajas que ayudan a la elaboración y posterior lectura del mapa, a saber:

- Facilita la confección de los MC cuando cuentan con un elevado número de conceptos.
- Agiliza el proceso de refinamiento que conduce al mapa definitivo.
- Facilita la interconexión entre distintos mapas. Esto resulta de gran valor cuando se conecta un mapa M con otros relativos a los conocimientos previos de M. El establecimiento de las relaciones cruzas entre todos esos mapas permite visualizar la integración del nuevo conocimiento con los ya adquiridos.
- Favorece la extensión de un MC ya elaborado al que hay que agregarle elementos nuevos.
- Agiliza la modificación de los MC ya que se puede cambiar alguno de sus elementos sin necesidad de rehacerlo.
- Permite la asociación de variadas apariencia para cada uno de los conceptos que conforman el mapa.
- Posibilita el acceso a la información de manera rápida y plantea una interacción lector-autor más activa.
- Como un MCH está compuesto por vistas, es posible tener en pantalla un mapa que no supere los siete u ocho conceptos; atendiendo a estudios vinculados con el tema de la percepción es recomendable que el número máximo de conceptos que lo componen no sea superior a siete (Novak, 1984). Además, como el número de vistas no es limitado se puede trabajar con mapas de elevado número de conceptos sin interferir en los beneficios que tienen, desde el plano de la percepción, los mapas con pocos conceptos.

- Promueve el trabajo de selección y jerarquización de los conceptos al tener que particionar el mapa en vistas. Esto y la posibilidad de establecer relaciones cruzadas diferencian a los MCH de otras propuestas que asocian MC con hipermedia, como por ejemplo la propuesta de Gaines y Shaw (Gaines y Shaw, 1993).

2.1 Plataforma para el trabajo con MCH

El diseño de una plataforma específica para el tratamiento de MCH apunta a contar exclusivamente con aquellos recursos necesarios para el desarrollo de los mismos. La Plataforma MCH cuenta con esas características [Mor96a]. Presenta dos modalidades de trabajo, una de ellas es el modo correspondiente al autor en el cual se elabora y modifica el mapa y la otra correspondiente al lector en la que el mapa puede ser recorrido e inspeccionado. Se permite una interacción inmediata entre ambas modalidades. La modalidad de autor presenta características específicas para la creación de los MCH que liberan totalmente al usuario del tratamiento de cualquier aspecto superfluo a la comprensión del tema. Cuenta con una interface gráfica y amigable que ofrece una barra de herramientas con las distintas opciones disponibles para la construcción y modificación del mapa y con los menús desplegables propios para el trabajo de edición.

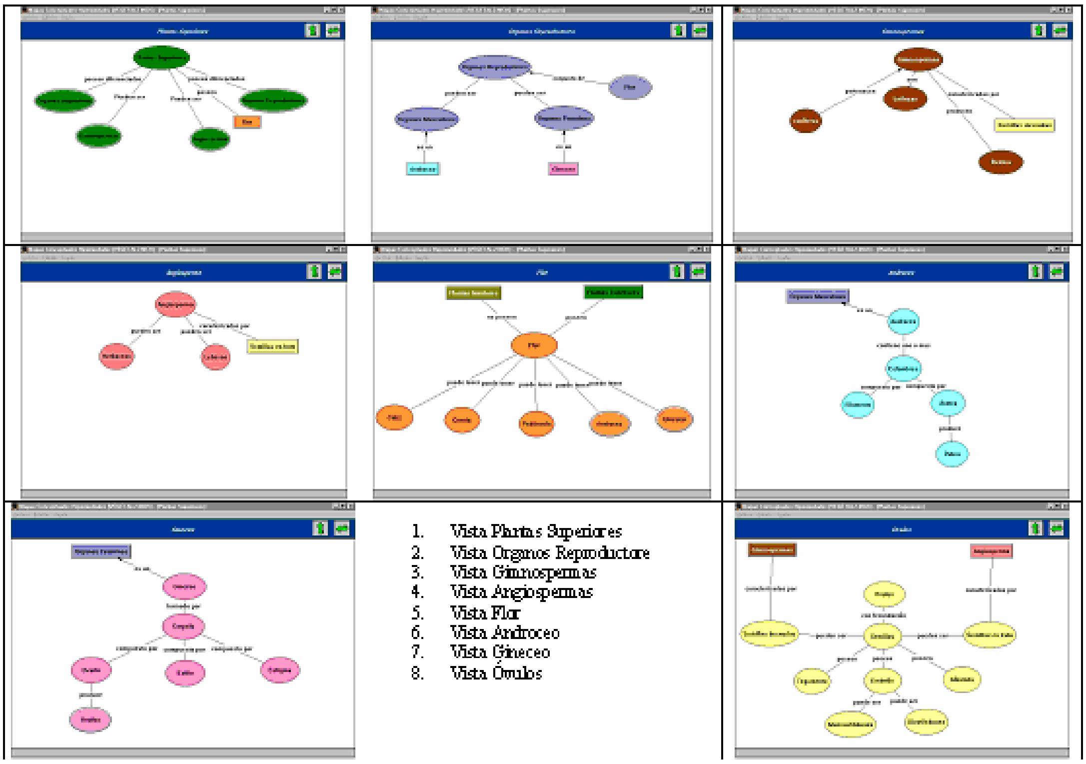

Figura 1: Ocho vistas de un MCH sobre el Reino Vegetal

2.2 Herramientas para la visualización de foco y contexto en un MCH

El saldo positivo que se logra con la partición del mapa en vistas (desde lo pedagógico y desde lo operacional), puede tornarse negativo si el lector del mapa pierde las referencias conceptuales con respecto al todo mientras centra su atención en una vista particular. Si bien la metodología propuesta para la creación de los MCH subsana los aspectos operacionales que dificultan la creación de los MC tradicionales, introduce las características propias de la hipermedia. Los problemas inherentes a la lectura o navegación de una hipermedia, sumados a la importancia de poder visualizar el MCH de una manera global, integrando todas las vistas en una única representación visual determinaron la necesidad de incluir dentro del ambiente una herramienta para ese fin. El Grafo Integrador Anidado de un MCH (GIA_{MCH}) es el resultado de la integración de herramientas desarrolladas previamente, cada una de ellas favoreciendo distintos aspectos en la interacción de los usuarios con los MCH. A modo de ejemplo en la **Figura 1** se muestran ocho vistas, de un MCH sobre el Reino Vegetal, generadas con la Plataforma MCH. Para el trabajo de construcción de conocimiento dentro de un *Ambiente de aprendizaje MCH* resulta de sumo interés poder visualizar todas las vistas de un MCH en forma integrada, como si fuese un MC tradicional al que se le adiciona el código cromático y diferentes apariencias en la representación de los conceptos. Con ese propósito se definió el Grafo Integrador de un MCH (GI_{MCH}), una herramienta que genera de forma automática el grafo síntesis de las vistas que lo componen (Martig y Señas, 2000).

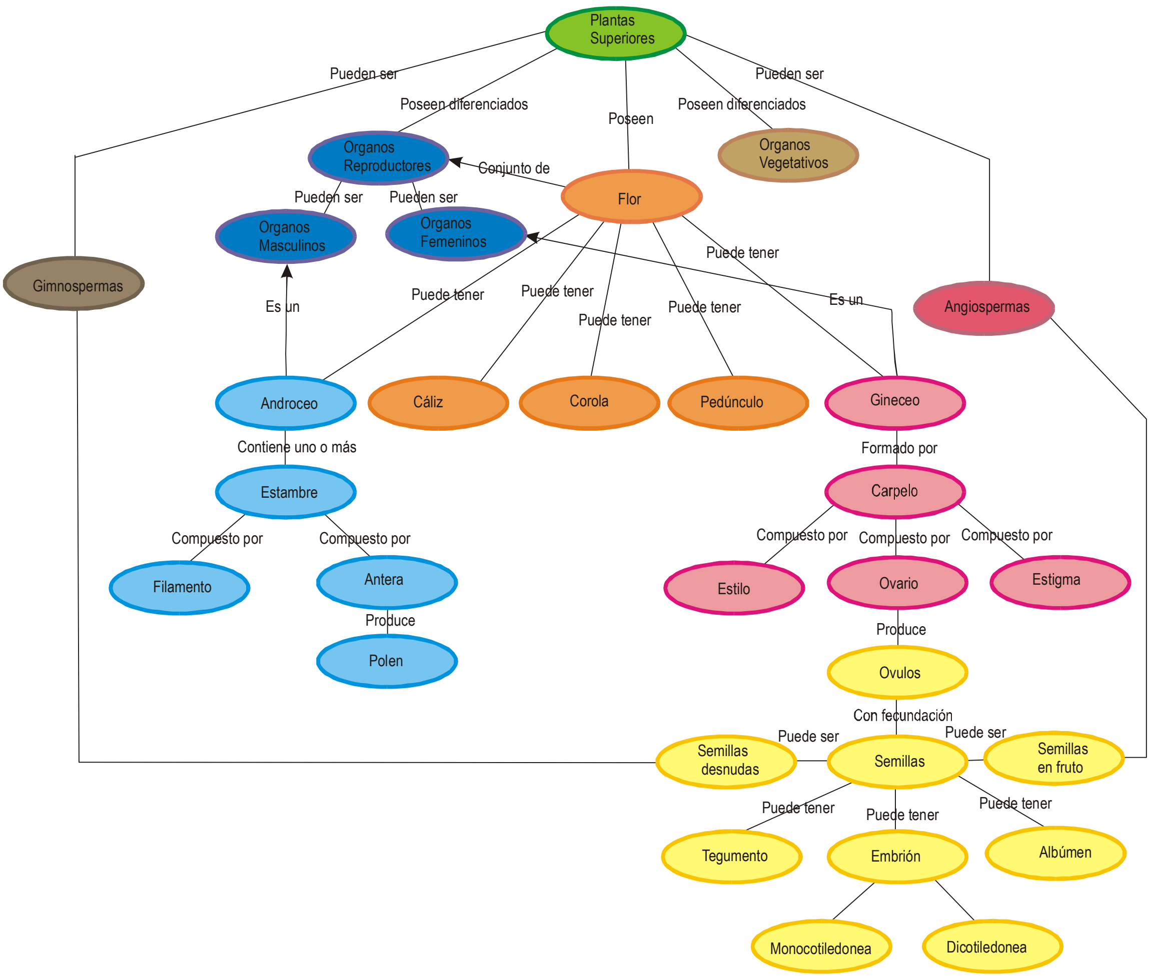

Figura 2: GI de las ocho vistas mostradas en la **Figura 1**

Provee la posibilidad de tener una visión global de todo el mapa, posibilitando la integración conceptual de todas las vistas en una única representación visual. En la **Figura 2** se muestra el $GI_{ReinoVegetal}$ resultante de la integración de las mismas. Si bien el GI_{MCH} es una herramienta valiosa dentro del ambiente, la posibilidad de contar con una gran cantidad de nodos (conceptos) conlleva no sólo el problema de su dibujado, sino también el de su lectura e interpretación. Por otro lado debido a las características propias de los MCH, el usuario (autor/lector) al recorrer el mapa, ya sea durante el proceso de creación o de consulta, no tiene la visión simultánea de todas las vistas del mapa. Es decir el autor/lector tiene foco sobre la vista actual, pudiéndole surgir la necesidad de tener visible el contexto de esa vista dentro del MCH en cuestión. Una manera de brindar el contexto de una vista es mostrar las relaciones existentes entre todas las vistas que componen el MCH, para que el usuario al consultar el mapa de las vistas del MCH pueda extraer la información contextual que necesite. Esta fue la motivación para la creación del Grafo de Vistas de un MCH (GV_{MCH}) (Martig y Señas, 2001). En la Figura 3 se muestra al GVReinoVegetal correspondiente a las 8 vistas mostradas en la Figura 1.

El GIA_{MCH} es una herramienta que a partir del GV_{MCH} de un MCH creado previamente, en forma transparente para el usuario; permite que el usuario interactivamente especifique qué zonas del mapa quiere ver con detalle, manteniendo siempre el marco contextual. Se trata de integrar lo mejor de dos mundos, presentar la información con distinto grado de detalle, fomentando la exploración del mapa y permitiendo mantener un número aceptable de elementos simultáneamente en pantalla. Desde el punto de vista del modelo el GIA_{MCH} es un grafo jerárquico que inicialmente representa el GV_{MCH}, con las características que le son propias, pudiendo a voluntad del usuario incluir información a nivel del detalle de vistas. El dibujo mostrado en pantalla, cumple una doble función: Por un lado permite la visualización en una misma ventana de información contextual y el detalle de las áreas de interés del usuario. Por otro parte actúa como interfaz, siendo el medio a través del cual el usuario establece qué elementos desea expandir.

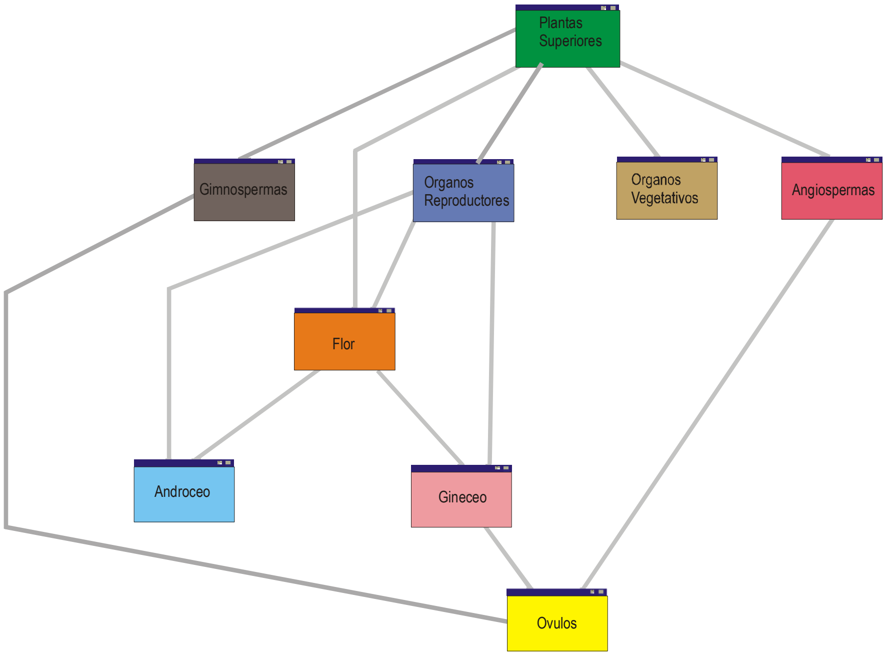

Figura 3: $GV_{ReinoVegetal}$. Grafo de las ocho vistas mostradas en la **Figura 1**

Para poder visualizar en una misma ventana información contextual conjuntamente con el detalle a nivel de las vistas de un MCH es necesario distinguir dos tipos de elementos:

– Elementos de Información Contextual: Como se expresó en el GV la información contextual se logra con un grafo cuyos nodos representan a las vistas del MCH y cuyas aristas simbolizan la existencia de al menos una relación entre los vértices que unen.

- Los nodos están rotulados con el nombre de la vista que representan.
- Los nodos mantienen la codificación cromática de la vista representada en el MCH original.
- Funcionalmente los nodos actúan como botones que pueden expandirse incorporando en su lugar el grafo jerárquico con el detalle de la vista representada.
- Las relaciones existentes entre nodos vistas también pueden al ser seleccionadas expandirse incorporando los grafos correspondientes a las vistas involucradas (extremos de la relación).

– Elementos a nivel del Detalle de Vistas: A este nivel lo que se debe mostrar son los grafos jerárquicos representando a las vistas, en un grafo tal los nodos representan conceptos propios terminales y las aristas relaciones entre los conceptos que unen.

- El nivel asociado a cada nodo respeta la jerarquía en el MCH de los conceptos representados.
- Los nodos mantendrán el código cromático que tiene la vista en la que aparecen como terminales en el MCH original.
- Se mantiene la asociación de apariencias.

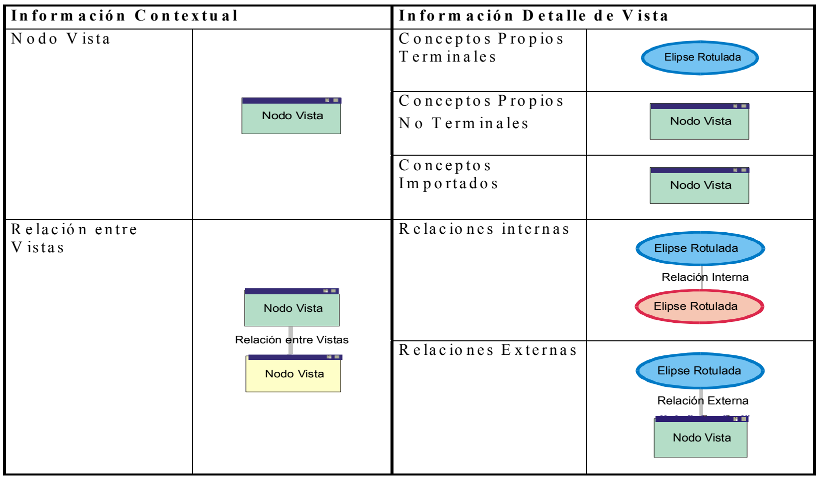

Figura 4: Elementos de un GIA_{MCH} y sus representaciones

Para que gráficamente se diferencie la naturaleza de la información mostrada se utilizará la representación indicada en la Figura 4. De lo expuesto, el $GV_{ReinoVegetal}$ mostrado en la Figura 3 constituye el $GIA_{ReinoVegetal}$ inicial. Además de las interacciones individuales sobre los nodos vista y sobre las relaciones, el usuario cuenta con la posibilidad de realizar selecciones múltiples. En el caso extremo que se explotaran todas las vistas se convierte en el GI_{MCH}. En la Figura 5 se muestran los resultados de interacciones sobre un Nodo Vista y sobre una arista del $GV_{ReinoVegetal}$ de la Figura 3 En (a) se explotó el nodo Vista Gineceo y en (b) se muestra el resultado de explotar la arista entre los nodos Gineceo y Flor.

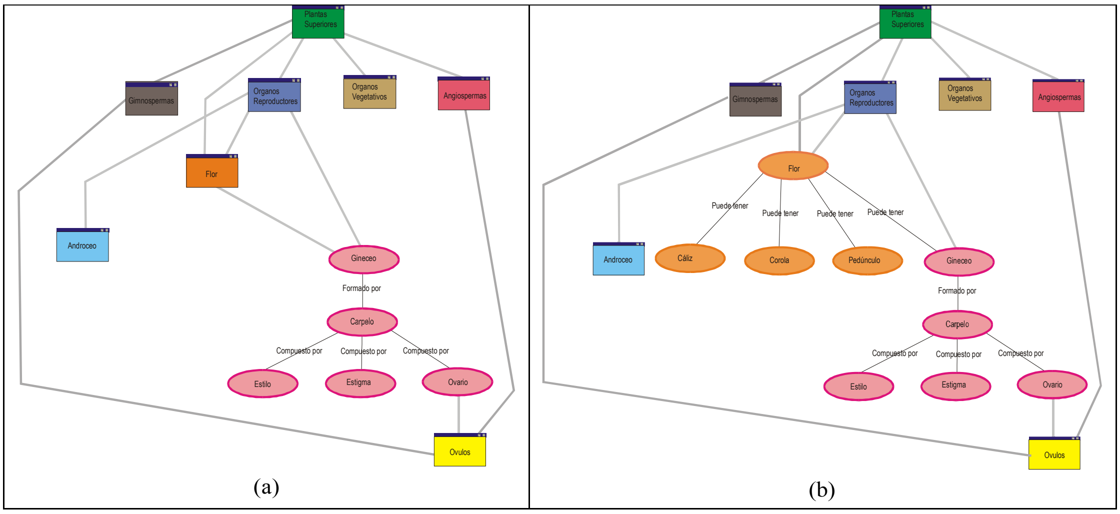

Figura 5: Resultado de dos interacciones posibles sobre el $GIA_{ReinoVegetal}$

Es importante destacar que la Plataforma MCH construye automáticamente estas herramientas aptas para la visualización del mapa.

2.3 Una experiencia en el aula con MCH.

El alumno, al poner en marcha una estrategia, debe disponer de recursos alternativos, entre los cuales decide utilizar, en función de las demandas de la tarea de aprendizaje que se le presenta, aquellos que considera mejores. Sin una variedad de recursos no es posible actuar estratégicamente. Una vez creados los MCH y su entorno de trabajo surgieron en forma natural los siguientes interrogantes ¿son los MCH una estrategia de aprendizaje?, ¿podrían constituirse en una estrategia de enseñanza?, ¿existen ventajas comparativas entre los MCH y los MC tradicionales? Las respuestas a estos interrogantes se comenzaron a construir a partir de las conclusiones obtenidas luego del desarrollo de una experiencia educativa con MCH y MC tradicionales que abarcó cursos paralelos en campos disciplinarios distintos. Se consideraron tres tendencias de evaluación diferenciadas: diagnóstica, formativa y sumativa, a través de la aplicación de procedimientos cualitativos y cuantitativos.

2.3.1 Descripción de la experiencia

La experiencia en aula se realizó en la misma institución educativa y en dos disciplinas distintas: Ciencias Naturales y Ciencias Sociales. Para poder obtener las conclusiones se dejaron fijos los siguientes parámetros: edad de los alumnos, nivel socio-económico del grupo, docente del curso, disciplina, tema, período del año lectivo. Para cada una de las dos disciplinas mencionadas se tomaron dos cursos de características similares y bajo la responsabilidad del mismo docente desarrollaron la experiencia en forma paralela; en uno de los cursos se trabajó con MCH y en el otro con los MC tradicionales. Se desarrolló totalmente. Los condicionantes de la tarea se mantuvieron constantes a lo largo del desarrollo de la experiencia: composición de los grupos con sus respectivos docentes, características etarias similares (tercer año del tercer ciclo de la EGB- Alumnos de quince años, disponibilidad de recursos escolares (físicos y materiales) equivalentes. Se presenta a continuación el esquema de los cursos participantes y la notación referencial que será utilizada en el resto del trabajo.

	Ciencias Sociales	**Ciencias Naturales**
Trabajo con MC	$[MC]_{CS}$	$[MC]_{CN}$
Trabajo con MCH	$[MCH]_{CS}$	$[MCH]_{CN}$

Con el propósito de analizar el estado inicial de los alumnos, de acuerdo a las tendencias de evaluación explicitadas, se instrumentó una encuesta de diagnóstico, indagando acerca de sus conocimientos previos en la técnica de MC y su aplicación. A partir de la información obtenida en esta evaluación, el grupo de investigación decidió instrumentar dos sesiones de clases con la estrategia de MC, para lograr la construcción de una base común, en lo relativo a la comprensión de la técnica y a sus posibilidades de aplicación. Durante el transcurso de la experiencia el grupo de investigación implementó una evaluación de tipo formativa, realizando observaciones de diversas instancias áulicas, en las cuales se consideró: interés de los alumnos, clima del aula, impacto de la novedad en el caso de los MCH, actitud de los docentes, grado de correlación entre la comprensión de la técnica y su aplicación. Para el caso de la evaluación sumativa, en la cual se trabajó con los productos elaborados por los alumnos (MC y MCH) se tuvieron en cuenta: el número de conceptos reconocidos, las relaciones correctamente establecidas, la validez de las proposiciones, la jerarquización (como diferenciación progresiva), las conexiones cruzadas y los ejemplos.

2.3.2 Evaluación de la experiencia

De los resultados obtenidos a partir del procesamiento de las encuestas tomadas al finalizar el curso, se desprende que la mayoría de los alumnos que trabajaron con MCH encontraron que la tarea no les resultó difícil, mientras que el 25 % de los alumnos que trabajaron con MC tradicionales tuvieron dificultades en la confección del mapa, fundamentalmente al tener que hacer el trabajo de refinamiento, según consta en numerosas observaciones finales de encuestas de los grupos MC_{cs} + MC_{cn}. Teniendo en cuenta que los temas se mantuvieron iguales para los alumnos de ambos grupos, esta discrepancia de respuestas se debe a que los alumnos de los grupos MCH_{cs} y MCH_{cn} encontraron más fácil y rápido el diseño espacial del mapa y su corrección. En cuanto a su uso, más de la mitad de los alumnos están familiarizados con la técnica de MC, pero se incrementa su uso en el caso de MCH. Es interesante observar como la técnica multimedial y el uso de la computadora estimula al estudiante al uso de la herramienta, aunque el estudio sobre la unión de los cuatro grupos muestra que un 90 % encuentra la técnica útil y un 60 % muy agradable, independientemente de la tecnología hipermedial. Especial atención debe darse a la experiencia áulica. Ambos grupos de alumnos debieron fortalecer la técnica de MC, pero para aquellos que aprendieron los MCH debe agregarse el tiempo de práctica en máquina. El 38% encuentra la experiencia como tediosa para realizar MC pero sólo el 13% lo hace en el caso de MCH a pesar de que el período de adaptación fue mucho más largo. Este tiempo incluye la revisión de la técnica de MC, el estudio de la plataforma y el entrenamiento en el diseño del MCH. De cualquier manera, este resultado se ve compensado por el hecho de que este último grupo encuentra que el producto final es mucho más ordenado, prolijo, fácil de corregir y de ampliar. Si comparamos los resultados anteriores discriminados por disciplina, debe destacarse que la concreción de un mapa semánticamente correcto es más difícil de obtener cuando se trabaja sobre temas de las Ciencias Sociales que sobre temas propios de las Ciencias Naturales. En primer lugar, la ilación en el tiempo de un proceso social, el entrecruzamiento de las relaciones y la dificultad de clasificación (generalización / especialización) hacen que los MC deban ser pensados y diseñados con extremo cuidado. En segundo lugar, las Ciencias Naturales se relacionan más con las tareas taxonómicas y es más simple de establecer las causas/consecuencias de un hecho. Ello explica que el 25 % de los alumnos del grupo MC_{cs} + MCH_{cs} haya encontrado difícil la tarea mientras que sólo un 10 % de MC_{cn} + MCH_{cn} responde de igual modo.

3 Conclusiones

Los MCH constituyen un recurso poderoso para la representación de las ideas, plasman los conceptos fundamentales y sus relaciones. Su uso es beneficioso para investigadores y profesionales de distintas disciplinas, quienes pueden contar con una herramienta específica para la representación del conocimiento. Desde lo didáctico, suman la riqueza de los MC y el poder de la hipermedia, constituyéndose en una moderna tecnología educativa para el trabajo sobre meta-aprendizaje y meta-conocimiento. El *Ambiente MCH* que se ha presentado es un recurso valioso en el marco de la construcción del conocimiento, permite trabajar expresamente sobre la relación correcta entre los conceptos recientemente aprendidos y los previos o entre diversos enfoques de un mismo tema. El trabajo de selección y partición en vistas que debe realizar el autor del mapa aleja esta propuesta de otras que también usan la computadora para elaborar MC.

4 Reconocimientos

Este trabajo forma parte del proyecto “Agentes Pedagógicos para Sistemas de Aprendizaje Interactivos” que se desarrolla con un subsidio otorgado por la Universidad Nacional del Sur (Argentina). 2001-2004.

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¿CÓMO HACER EFICACES LOS MAPAS CONCEPTUALES EN LA INSTRUCCIÓN?

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Resumen. Para conocer bajo qué condiciones son más efectivos los mapas conceptuales, se realizó el presente estudio con 270 alumnos de bachillerato, que, antes de la exposición didáctica, elaboraban un mapa o era el profesor quien lo presentaba. En el primer caso, los contenidos podían ser académicos o experienciales (cotidianos). A su vez, estas modalidades fueron combinadas con distintas estrategias instruccionales (por ejemplo: confrontación y conexión). Los principales resultados resaltan el valor de los mapas conceptuales como organizadores previos, especialmente, cuando son presentados por el profesor acompañados de una actividad de confrontación con el tema por los alumnos, o cuando éstos elaboran los mapas y es el profesor el que los conecta con el tema objeto de enseñanza.

1 Introducción

En las últimas décadas ha tenido un gran auge el uso de los mapas conceptuales, especialmente, como una herramienta útil en la enseñanza para fomentar el aprendizaje significativo (Novak, 1998).

Un mapa conceptual es una representación gráfica de varios conceptos y sus interrelaciones. Como señalan Novak y Gowin (1984), se trata de un instrumento esquemático para representar un conjunto de significaciones conceptuales integradas en una estructura de proposiciones. El mapa conceptual generalmente está formado por "nodos" (conceptos) y "enlaces" (líneas) entre ellos. Estos enlaces suelen estar etiquetados con una oración o verbo indicando algún tipo de propiedad de uno de los conceptos respecto a otros. Esto supone un modo esquemático, pero al mismo tiempo "vivo" y ágil de exponer y captar la información.

Especialmente, es un instrumento para promover el aprendizaje significativo, sobre todo en ciencias (Novak y Gowin, 1984). Con ello, el alumno tiene un papel activo, relacionando el nuevo conocimiento con los ya adquiridos, a diferencia del aprendizaje memorístico en el que se relaciona aleatoriamente la nueva información con representaciones ajenas al propio significado. En la base de todo esto está la *perspectiva constructivista*, en la que se defiende que el aprendizaje es un proceso activo por el que el alumno está constantemente creando y revisando las interpretaciones internas de su conocimiento (Duffy y Jonassen, 1992).

A pesar de la gran popularidad que los mapas conceptuales han tenido y siguen teniendo, "las justificaciones y resultados sobre ellos están siendo exagerados y distorsionados por muchos informes" (Jonassen, et al 1997). También hay que reconocer que el número de investigaciones, aunque creciente, es pequeño y necesita de un esfuerzo científico por superar sus limitaciones empíricas (Jonassen, et al 1997). Esto es lo que nos invita, máxime sabiendo de la importancia del tema, a profundizar y conocer, con la presente investigación, los distintos aspectos que influyen en la eficacia de los mapas conceptuales. Antes, hay que considerar que las dificultades de su estudio, entre otras razones, son debidas a la variedad de aplicaciones que los mapas conceptuales tienen. En la revisión que nosotros hemos hecho, las hemos sintetizado en tres: 1) los mapas conceptuales usados como instrumento y estrategia para *evaluar* y *valorar* los conocimientos y sus procesos, 2) como instrumento y estrategia de aprendizaje para incrementar las *habilidades metacognitivas* y 3) como instrumento y estrategia de *enseñanza*.

2 Método

2.1 Objetivos y variables

El propósito general de esta investigación es conocer bajo qué condiciones instruccionales resultan más efectivos los mapas conceptuales cuando son usados antes de la exposición de los contenidos didácticos (presentados, en este caso, a través de un video de ciencias naturales, para garantizar un mayor rigor metodológico). Para ello, contemplamos cinco variables (quién, qué, cómo, cuántas y cómo se evalúa), siendo las cuatro primeras variables independientes y la quinta, dependiente, tal como se aprecia en la tabla 1.

Variables independientes	Valor de cada variable
1.¿*Quién* elabora el mapa conceptual?	*a) Profesor* *b) Alumnos*
2.¿*Qué* tipo de contenidos es evocado?	*a) Académicos* *b) Experienciales*
3.¿*Cómo* se relaciona el mapa conceptual con la nueva información, objeto de aprendizaje?	*a) Conexión* *b) Confrontación* *c) No se relaciona*
4.¿*Cuántas* estrategias se ponen en juego a la vez?	*a) Condición simple (una sola estrategia)* *b) Condición doble (suma de dos simples)* *c) Condición compleja (suma de tres simples)*
Variables dependientes	**Valor de cada variable**
5. ¿*Cómo* se evalúan los objetivos de aprendizaje?	*a) "Conocer"* *b) "Comprender"* *c) "Usar" o "aplicar* *d) "Generar"* *e) Puntuación total*

Tabla 1: Variables y valores de los mapas conceptuales previos a la instrucción

Siguiendo la tabla 1, se observa que una primera variable independiente surge de preguntarse: "¿Quién elabora el mapa conceptual?" Para lo cual consideramos dos valores o posibilidades: a) que lo elabore *el profesor* ("mapa-modelo", basado en el contenido que se va enseñar, por lo tanto, en el video didáctico), y, b) que lo elaboren los propios *alumnos* (mapa basado en los conocimientos previos respecto a lo que se va a aprender).

Una segunda variable independiente surge del tipo de contenidos que es evocado. En este caso consideramos que la evocación también puede referirse a dos modalidades: a) la que se apoya en *contenidos académicos* (mapa elaborado por los alumnos basado en sus conocimientos escolares) y b) la que se apoya en *contenidos experienciales* (mapa elaborado por los alumnos basado en sus conocimientos cotidianos).

Una tercera variable independiente se deduce del modo en el que se relaciona el mapa conceptual con la nueva información, objeto de aprendizaje. Aquí consideramos tres valores o posibilidades: a) se relaciona mediante *conexión* (el profesor hace relaciones entre los mapas elaborados por los alumnos las ideas principales que aparecerán en la nueva información o vídeo didáctico); b) se relaciona mediante *confrontación* (el alumno tiene que comprobar lo expuesto en el mapa con lo que va apareciendo en la nueva información o vídeo didáctico); c) *no se relaciona* el mapa con la nueva información.

Una cuarta variable independiente se origina del nivel de complejidad de las estrategias instruccionales utilizadas. Concretamente: ¿Cuántas estrategias se ponen en juego a la vez?: *a) Condición simple* (una sola estrategia); *b) Condición doble* (suma de dos simples) *y c) Condición compleja* (suma de tres simples).

Por último, como variable dependiente, se consideran los resultados de los objetivos de aprendizaje, reflejados en los procedimientos evaluativos inferidos de distintas taxonomías (por ejemplo, las de Gagné y Briggs, 1974; Merrill, 1983), que son sintetizados por Hernández (1997 y 2001, pág. 88) así: *"Conocer", "Comprender", "Usar" y "Generar",* además de una puntuación total.

2.2 Participantes

La investigación se inició con 425 alumnos y alumnas de 14 a 15 años del antiguo bachillerato (2º de BUP), pertenecientes a dos institutos públicos de enseñanzas medias de La Laguna (Tenerife). Los dos centros están ubicados en una zona urbana, siendo la procedencia de los alumnos, en su gran mayoría, también urbana. Por motivos de equiparación en las condiciones experimentales y por mortandad experimental, se redujo la muestra a un total de 270 (58% alumnas y 42% alumnos). Con ellos se formaron 13 grupos experimentales (de 18 a 24 alumnos) asignados al azar a los diferentes tratamientos. Estos grupos experimentales estaban compuestos por subgrupos (de dos a cuatro) que habían recibido el mismo tratamiento en situaciones distintas y que habían sido equiparados según colegio, sexo, número de repetidores y rendimiento académico. Para esto último, se tuvieron en cuenta las notas obtenidas por los alumnos en junio del año anterior, de tal forma que la nota media que formaba cada grupo experimental estaba en torno 5.88. Para mantener este criterio, se tuvieron que eliminar algunos alumnos que desviaban significativamente al grupo, bien por encima o por debajo.

2.3 Diseño

Se trata de un diseño *cuasiexperimental* en el ambiente natural del aula, cuyas cuatro *variables independientes*, ya presentadas, dan lugar a los 13 tratamientos instruccionales indicados en la tabla 2, que tienen en común un vídeo didáctico sobre "El suelo". ¿Por qué 13 tratamientos? Siguiendo la tabla 2, se puede comprobar que, en las condiciones experimentales *simples,* están incluidas todas las modalidades. En las condiciones *dobles,* se excluyen las que no son posibles (por ejemplo, el mapa elaborado por el profesor no es compatible con la condición de conexión, ni con los contenidos experienciales). En las condiciones *complejas* (teóricamente múltiples), sólo se tuvieron en cuenta dos condiciones, que son las que hemos considerado más relevantes y más fácilmente reproducibles en el aula.

De los tratamientos, cuatro son *simples*: 1) *Control-placebo* (sin mapa, pero con actividades de relleno); 2) *Experiencial* (mapa elaborado por los alumnos basado en su conocimiento cotidiano); 3) *Académico* (mapa elaborado por los alumnos basado en su conocimiento escolar); 4) *Modelo* (mapa "guía" elaborado por el profesor basado en las ideas principales del video didáctico).

Siete tratamientos son *dobles*, con la unión de dos modalidades simples. En ellos, además de los citados, aparecen "la conexión" y "la confrontación". En "la conexión", el profesor relaciona el mapa elaborado por los alumnos con las ideas principales que se van a mostrar en el vídeo. En "la confrontación", los alumnos reciben por escrito la sugerencia de relacionar los conocimientos considerados en los mapas con los conocimientos que se van desarrollando a través del vídeo didáctico. Los tratamientos dobles son: 5) *Experiencial+modelo*; 6) *Académico+modelo*; 7) *Experiencial+confrontación*; 8) *Académico+confrontación*; 9) *Modelo+confrontación*; 10) *Experiencial+conexión* y 11) *Académico+conexión*.

	Nivel de complejidad		**Grupos, según las modalidades del uso de los mapas conceptuales**
CONDICIONES EXPERIMENTALES	Simples	1	*Control –placebo* (sin mapa y con actividades de relleno)
		2	*Experiencial* (mapa elaborado por los alumnos basado en sus conocimientos cotidianos).
		3	*Académico* (mapa elaborado por los alumnos basado en sus conocimientos escolares).
		4	*Modelo* (mapa elaborado por el profesor, basado en el video didáctico) .
	Condiciones dobles (suma de dos simples)	5	*Experiencial+modelo*
		6	*Académico+modelo*
		7	*Experiencial+confrontación* (comprobar mapa experiencial con el vídeo)
		8	*Académico+confrontación* (comprobar mapa académico con el vídeo)
		9	Modelo+confrontación (comprobar mapa del profesor con el vídeo)
		10	*Experiencial+conexión* (el profesor relaciona el mapa experiencial con las ideas principales del vídeo)
		11	*Académico+conexión* (el profesor relaciona el mapa académico con las ideas principales del vídeo)
	Condiciones complejas (suma de tres simples)	12	*Experiencial+modelo+confrontación*
		13	*Académico+modelo+confrontación*

Tabla 2: Distintas modalidades de mapas conceptuales utilizados en la investigación

Por último, dos tratamientos son *complejos* (formados por tres tratamientos simples): 12) *Experiencial+modelo+confrontación* y 13) *Académico+modelo+confrontación*.

La variable dependiente es el rendimiento de los alumnos recogido por una prueba sobre los contenidos del vídeo didáctico, con preguntas de cuatro modalidades evaluativas: *conocer, comprender, usar y generar* (Hernández, 1997 y 2001, pág. 88), siguiendo taxonomías como las de Gagné y Briggs (1974), y Merrill (1983).

2.4 Materiales

Vídeo didáctico.- El material de aprendizaje fue un tema de Edafología, incluido en el curriculum de Ciencias Naturales, titulado *"El Suelo",* correspondiente a Bachillerato, expresado a través de un vídeo didáctico realizado por especialistas en Edafología y, más en concreto, referido a los suelos de Canarias, del que hemos seleccionado unos 12 minutos para su exposición (Serio, 1997; Hernández, Sosa y Serio, 1998). El vídeo consta de tres grandes apartados: 1) *Importancia del suelo*, donde se expone la relación entre el ser humano y suelo a través de la historia, así como aquellos factores que intervienen en la formación del suelo. 2) *Fases de formación de un suelo*, donde se hace referencia a las distintas etapas que se suceden para la formación de un suelo maduro.3) *Suelos canarios*, donde se recogen los distintos tipos de rocas y suelos, los factores que influyen en su formación, aludiendo a las distintas zonas climáticas, a los microclimas, a los tipos de vegetación, a los diferentes tipos de cultivo y a las consecuencias ecológicas de la devastación de la naturaleza.

Se trata de un material suficientemente "difícil" que permite discriminar mejor los efectos de las distintas condiciones experimentales. En los métodos expositivos de enseñanza, los profesores pueden modular su discurso en función de una serie de variables, como son sus expectativas hacia determinados grupos, atribuciones, cansancio, etc. La elección de un material estandarizado, como es un video didáctico, responde a la necesidad de control, de que los alumnos de distintas condiciones experimentales reciban los mismos contenidos, en el mismo tiempo y expresados de la misma forma.

Cuaderno de instrucciones.- En él se exponen: 1) Las instrucciones escritas iguales para todos los grupos, indicando que se va a visionar un video dedicado a "El suelo", donde se pide que presten atención, pues al final tendrán que contestar a una serie de preguntas referidas al contenido del mismo. *2*) Las instrucciones específicas de cada condición experimental.

Cuestionario evaluativo.- Está formado por 11 cuestiones de las que se derivan un total de 37 ítemes (unidades de respuesta), que recogen las principales categorías evaluativas ya indicadas (*conocer, comprender, usar y generar*).

En la categoría "conocer" (formada por 5 cuestiones y 12 ítems) se les pregunta de forma literal por contenidos recogidos en el video (Ej.: "Escribe tres de los cinco factores que contribuyen a la formación del suelo"). En la categoría "comprender" (formada por 3 cuestiones y 6 ítems) se les pregunta de forma distinta a como aparecen los contenidos en el video para comprobar si realizan un aprendizaje más significativo (Ej.: "Escribe con tus palabras por qué el suelo es "dinámico"). En la categoría "usar" la información (formada por 2 cuestiones y 9 ítems), se les pide que realicen deducciones o aplicaciones de la información dada, de acuerdo con el BIG de Perkins (*Beyond information given*, "ir más allá de la información dada"), por ejemplo, se plantean situaciones hipotéticas: "¿Cómo sería el clima de Tenerife si se cortaran sus montañas y se redujera su altitud a 400 metros? ¿A qué islas actuales se parecería?". En la categoría "generar" (formada por 1 cuestión y 10 ítems) se les pide que obtengan, sin aprendizaje previo asociado, soluciones o alternativas a situaciones problemáticas nuevas. Esto coincide con el concepto WIG de Perkins (*Without information given*, "sin información dada"). Concretamente, se pregunta: "¿Qué posibles consecuencias y aplicaciones se te ocurren del estudio científico del suelo?".

Con esta batería formada por distintos tipos de preguntas se pretende averiguar cuáles son las modalidades instruccionales que producen mejores resultados y en qué tipos de aprendizaje. Las preguntas de evaluación son de tipo evocativo (sólo una de reconocimiento), teniendo que contestar de forma simple, con un término o concepto, o de forma compleja, con un breve texto, inferior a dos líneas.

Para la corrección de la prueba se establecieron, previamente, unos criterios de adecuación de las respuestas consensuados por tres jueces. Además, en la fase de corrección, se sometían aquellas respuestas dudosas a una comparación "interjueces".

La puntuación de la prueba se obtenía según el valor directo previamente atribuido a cada una de las cuestiones e ítems. Así, a cada ítem (unidad de respuesta) correcto se le asignó una puntuación directa de 1. Luego, las puntuaciones de cada modalidad evaluativa (*conocer, comprender, usar y generar*) se transformaron, proporcionalmente, en una escala de 0 a 5, para poder ser comparadas entre sí. Por último, se obtuvo una "Puntuación total media" con la suma de todas las categorías, en una escala de 0 a 10.

La fiabilidad obtenida entre las cuatro categorías en la corrección de la prueba garantiza una elevada consistencia interna de la misma, obteniendo un alfa de Cronbach de 0,87, presentando las cuatro subescalas una alta correlación con el conjunto (*conocer* = 0,67; *comprender* = 0,79; *usar* = 0,63 y *generar* = 0,79).

2.5 Procedimiento

Hay que tener en cuenta que los alumnos ya conocían el uso y manejo de los mapas conceptuales. La sesión experimental se llevó a cabo en clase durante una hora, distribuida en cinco momentos:

En el *primer momento*, se explicaba de forma verbal lo que se iba a hacer y se les agradecía su participación.

En el *segundo*, se presentaba una actividad previa al desarrollo del tema. Para ello, se les daban las siguientes instrucciones escritas, iguales para todos los grupos: "*A continuación vamos a visionar el documental titulado ¿Qué es el suelo? Su duración es de aproximadamente 12 minutos y está referido a los suelos de Canarias. Presta mucha atención pues al final tendrás que contestar a una serie de preguntas referidas al contenido del video".* El resto de las instrucciones de esta actividad previa variaba en función del grupo experimental.

Así, el grupo que elaboraba el mapa conceptual experiencial recibió las siguientes instrucciones escritas: Antes de comenzar a ver el video, escribe en el cuaderno de trabajo todos los conceptos o términos relacionados con el suelo, con el terreno que tú recuerdas como fruto de tu experiencia. De esta forma podrías hablar de los terrenos pensando en tu infancia, en tu familia, en tus juegos, en el trabajo, en tus excursiones, en lo que has visto..., o en cualquier actividad relacionada con el terreno. Tienes 5 minutos". Mientras que las instrucciones del mapa conceptual académico eran: ""Antes de comenzar a ver el video, escribe en el cuaderno de trabajo todos los conceptos o términos relacionados con el suelo que recuerdes haber aprendido en años anteriores en clase, o a través de los libros. Tienes 5 minutos".

Después de la evocación de conceptos por parte de los alumnos, tanto academicistas como experienciales, elaboraban un mapa conceptual con dichos conceptos.

Las instrucciones para el grupo que recibía el mapa conceptual elaborado por el profesor, fueron las siguientes: "A continuación observa el conjunto de conceptos que tratan sobre términos relacionados con el suelo. Obsérvalo y estúdialo bien durante cinco minutos". Seguidamente, se les presentaba un mapa conceptual elaborado por el profesor basado en los conceptos descritos en el video.

Los alumnos del grupo control-placebo recibieron las siguientes instrucciones: "Escribe por orden de preferencia de más a menos las asignaturas que más te gustan". Y también: "Escribe las profesiones que te gustaría desempeñar en el futuro. Para ello dispones de 5 minutos".

En el tercer momento, se daban instrucciones específicas en función de las distintas modalidades experimentales, por ejemplo: a) comentarios de conexión entre los mapas elaborados y el tema que iban a ver; b) instrucciones para que los alumnos confrontaran los mapas con el tema que se les expondría; c) ninguna instrucción especial.

Las instrucciones del grupo que recibió "la conexión" fueron de tipo verbal a cargo del profesor. Éste les pedía que evocaran los conceptos que habían escrito en sus cuadernos de trabajo sobre "El suelo". Luego, él los relacionaba con los conceptos que aparecerían en el video. Cuando existían conceptos importantes del video que no eran nombrados por los alumnos, el profesor les daba pistas para que ellos mismos los descubrieran.

Las instrucciones escritas para el grupo que realizó "la confrontación" fueron las siguientes: "Mientras estés viendo el documental, trata de relacionar lo que veas en el video, con lo que hemos visto aquí".

En el cuarto momento, se exponía el tema "El suelo", a través del documento videográfico citado.

En el quinto momento, los alumnos realizaban la prueba de evaluación para comprobar el dominio adquirido. Esta prueba fue corregida teniendo en cuenta el valor previamente atribuido a cada una de las preguntas de cada modalidad evaluativa (conocer, comprender, usar y generar) sometiendo las respuestas dudosas a una comparación "Interjueces". Luego, las puntuaciones de cada modalidad se transformaron proporcionalmente en una escala de 0 a 5, para poder compararlas entre sí. Por último, se obtuvo una "Puntuación total media" con la suma de todas las categorías, en una escala de 0 a 10.

Actuó en todas las situaciones el mismo profesor, realizando tal papel uno de los investigadores. Se empleó el mismo contenido didáctico en todas las condiciones experimentales. Esto garantizó que la forma de explicar el tema y el tiempo dedicado al mismo fueran exactamente igual. Se balanceó el momento del pase de la prueba, haciendo que los alumnos de cada grupo experimental realizaran la prueba en distintos momentos de la mañana, evitando pasarla a última hora.

3 Resultados

Los principales resultados obtenidos figuran en la tabla 3. Recogen la media y desviación típica de cada condición experimental en cada uno de los modos de evaluación (*conocer*, *comprender, usar y generar*) que apresa el cuestionario evaluativo, así como su comparación con el grupo control, de acuerdo con el procedimiento aplicado de diferencia de medias (T-Student, concretamente, T-TEST del SPSS-PC+). El valor de las puntuaciones está ponderado, en un rango de 0 a 5, para poder ser comparadas entre sí. También, la puntuación total está reconvertida en una escala de 1 a 10, para hacer comparaciones más intuitivas y analógicas con los criterios escolares al uso en la realidad española.

Entre los principales resultados, observamos que, tanto en la *Puntuación total* como en las *distintas modalidades evaluativas,* las modalidades instruccionales que resultan superiores, significativamente, respecto al grupo control, son "Mapa Modelo+Confrontación", "Mapa Experiencial+Conexión" y "Mapa Académico+Conexión".

Modalidad experimental **Grupos**		**Modalidad evaluativa**								**PUNTUACIÓN TOTAL**, ponderada en una escala de 1-10	
		"CONOCER" *(Rango: 0-5)*		**"COMPRENDER"** *(Rango: 0-5)*		**"USAR"** *(Rango: 0-5)*		**"GENERAR"** *(Rango: 0-5)*			
Condiciones simples	**N**	**Media**	**SD**	**Media**	**SD**	**Media**	**SD**	**Media**	**SD**	**Media**	**SD**
MAPA ACADÉMICO	22	1,8	*1,2*	2,8	*1,7*	3,9	*1,4*	2,5	*2,6*	5,7	*2,3*
MAPA EXPERIENCIAL	19	1,5	*0,8*	2,4	*1,3*	***4,2***	*1,0*	2,6	*2,4*	5,2	*1,6*
MAPA MODELO	19	**2,3	*0,8*	2,6	*0,9*	4,0	*1,4*	2,1	*2,5*	***6,3***	*1,7*
Condiciones dobles (suma de dos simples)											
M. ACAD.+ M. MODELO	22	***2,0***	*1,1*	3,0	*1,3*	3,8	*1,4*	2,3	*2,5*	***6,1***	*2,5*
M. EXP.+M. MODELO	21	2,0	*1,0*	2,8	*1,3*	3,7	*1,5*	2,1	*2,5*	5,9	*2,5*
M. ACAD.+ CONFRONT.	20	1,7	*0,9*	2,2	*1,0*	3,6	*1,5*	1,2	*2,2*	4,9	*1,9*
M. EXP.+ CONFRONT.	19	1,8	*1,0*	2,5	*1,2*	3,4	*1,5*	2,1	*2,5*	5,4	*2,3*
M. MOD.+ CONFRONT.	20	***2,5	*0,8*	**3,3	*0,6*	**4,8	*0,6*	***3,2***	*2,4*	***7,3	*1,6*
M. ACAD.+ CONEXIÓN	23	***2,1***	*1,2*	**3,5	*1,2*	***4,4***	*1,2*	***3,3***	*2,4*	*7,0	*2,3*
M. EXP + CONEXIÓN	18	**2,6	*1,2*	***3,1***	*1,4*	***4,2***	*1,2*	***3,6***	*2,3*	*7,3	*2,5*
Condiciones complejas (suma de tres simples)											
M.ACAD.+M.MOD.+ CONFR.	24	1,8	*0,8*	***3,1***	*1,3*	3,3	*1,7*	2,7	*2,5*	5,6	*2,0*
M.EXP.+M.MOD.+ CONFR.	19	1,5	*1,1*	1,9	*1,3*	3,7	*2,0*	1,6	*2,4*	4,7	*2,4*
GRUPO CONTROL	24	1,5	*0,6*	2,6	*1,1*	3,8	*1,2*	2,7	*2,5*	5,5	*1,6*

Tabla 3: Puntuaciones medias y desviaciones típicas de los grupos experimentales en comparación con el grupo control

*Nota**: Cuadro resumen de las puntuaciones medias de los distintos grupos experimentales en comparación con el grupo control, en las distintas categorías de la variable dependiente, indicándose con asteriscos cuando las diferencias son significativas.***

* =Nivel de significación < 0.05
** =Nivel de significación < 0.005
***=Nivel de significación < 0.001
En negrilla y cursiva = Diferencias no significativas, pero próximas a serlo, con el interés de observar tendencias.

1) "Mapa Modelo+Confrontación", en la que el profesor presenta el "*Mapa-modelo*" y luego los alumnos llevan a cabo una actividad de *confrontación,* comprobando lo expuesto en el mapa con lo que va apareciendo en la nueva información o vídeo didáctico, resulta superior en la *Puntuación total*: t(20)=3,62;p<.001. Además, esta superioridad aparece también de forma significativa y específica en las modalidades evaluativas de "*conocer", "comprender" y "usar*".

2) "Mapa Experiencial+Conexión", en la que los alumnos realizan *mapas experienciales* (sobre conocimientos cotidianos) y luego el profesor hace relaciones entre esos mapas elaborados por los alumnos y las ideas principales que aparecerán en la nueva información o vídeo didáctico, resulta superior en la *Puntuación total*: $t(18)=2,63; p<.05$. Además, esta superioridad aparece también de forma significativa y específica en la modalidad evaluativa *"conocer"*.

3) "Mapa Académico+Conexión", en la que los alumnos realizan *mapas academicistas* (sobre conocimientos escolares) y luego el profesor hace relaciones entre esos mapas elaborados por los alumnos y las ideas principales que aparecerán en la nueva información o vídeo didáctico, resulta superior en la *Puntuación total*: $t(23)=2,54; p<.05$. Además, esta superioridad aparece también de forma significativa y específica en la modalidad evaluativa *"comprender"*.

Por otra parte hay que decir que el "Mapa Modelo del Profesor", por sí solo, se muestra efectivo en la modalidad evaluativa *"conocer"*.

3) "Mapa Académico+Conexión", en la que los alumnos realizan *mapas academicistas* (sobre conocimientos escolares) y luego el profesor hace relaciones entre esos mapas elaborados por los alumnos y las ideas principales que aparecerán en la nueva información o vídeo didáctico, resulta superior en la *Puntuación total*: $t(23)=2,54; p<.05$. Además, esta superioridad aparece también de forma significativa y específica en la modalidad evaluativa *"comprender"*.

Por otra parte hay que decir que el "Mapa Modelo del Profesor", por sí solo, se muestra efectivo en la modalidad evaluativa *"conocer"*.

En cuanto a las diferentes modalidades evaluativas, se observa el siguiente orden decreciente: En "*conocer"*, 3 resultados significativos ("Mapa Modelo"; "Modelo+Confrontación" y "Experiencial+Conexión"). En "*comprender*", 2 resultados significativos ("Modelo+Confrontación" y "Académico+Conexión"). En "*usar"*, 1 resultado significativo ("Modelo+confrontación"). En "*generar"*, ningún resultado significativo, aunque existe tendencia de superioridad en "Modelo+Confrontación"; "Académico+Conexión" y "Experiencial+Conexión".

4 Discusión y conclusiones

Vistos los resultados, se puede constatar lo que afirmábamos en el marco teórico: El mapa conceptual es efectivo, pero su efectividad no es absoluta, pues depende del modo y condiciones en que se emplee.

1. Sobre "quién" realiza los mapas.- Se confirma, considerando la "Puntuación total", que no se encuentran ventajas entre el mapa conceptual elaborado por el profesor y el elaborado por los alumnos. Las ventajas dependen más bien de otro tipo de condiciones, como son la *conexión* o la *confrontación*.

Ahora bien, de forma aislada, sin ninguna otra estrategia complementaria, parece evidente que el mapa elaborado por el profesor se muestra superior al grupo control-placebo aunque sólo en la modalidad evaluativa *"conocer"*.

2. Sobre "qué" tipo de contenido hay que evocar en la elaboración de los mapas.- ¿Qué es más beneficioso antes de la exposición de un tema, el que los alumnos elaboren los mapas conceptuales, partiendo de sus conceptos escolares previos (*perspectiva academicista)* o que lo hagan partiendo de los conceptos extraídos de la vida cotidiana (*perspectiva experiencial)*? Ante esto, los resultados de esta investigación nos indican que no hay diferencia entre uno u otro tipo de mapa. Esto ocurre en la condición simple (M. Experiencial y M. Académico), donde ninguno de los dos resulta efectivo por sí solo.

3. Sobre el "cómo" se relaciona el mapa conceptual con la nueva información.- En general, hemos considerado y confirmado empíricamente que relacionar los mapas conceptuales con la nueva información produce mejores resultados, tanto a través de la conexión como de la confrontación, aunque con matizaciones.

De forma particular, se ha verificado que tanto los mapas conceptuales experienciales como los académicos son eficaces si el profesor los conecta con el tema a tratar.

4. Sobre el "cómo" afecta la complejidad de tratamientos.- La conjunción acumulativa de dos tratamientos "yuxtapuestos", sin interconectar suficientemente y con escaso tiempo de consolidación, es inadecuada. Por ejemplo, el "mapa modelo del profesor", por sí mismo, es efectivo. Sin embargo, deja de serlo cuando se les pide a los alumnos que elaboren un mapa conceptual previo sin que medie conexión alguna ("M. Académico+Modelo" y "M. Experiencia+Modelo").

Los resultados obtenidos en esta investigación, aún teniendo en cuenta las limitaciones que una investigación compleja como ésta implican, vienen a demostrar que el uso del *mapa conceptual, como organizador previo puede ser eficaz, pero no todos los usos que se le den contribuyen a obtener un mejor aprendizaje*, es decir, no todas las modalidades del uso de mapas son eficaces en el aprendizaje de un nuevo contenido, tal como queríamos demostrar. Los mayores beneficios en el aprendizaje se producen en tres grandes condiciones:

1ª) Cuando el *profesor* presenta un mapa "*modelo*" previo al tema (M. Modelo).

2º) Cuando el *profesor* presenta un mapa "*modelo*" previo y, luego, les da la oportunidad a los alumnos para *chequear o confrontar* ese mapa con el desarrollo del tema (M. Modelo+Confrontación). Este es el procedimiento más efectivo, influyendo, incluso en la modalidad evaluativa *"usar"*, que implica ir más allá de la información dada.

3ª) Cuando los *alumnos* elaboran sus propios mapas conceptuales, tanto de tipo académico como experiencial, y, luego, el *profesor enlaza o conecta* los contenidos suscitados en los mapas con los que posteriormente se desarrollan en el tema.

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LOS MAPAS CONCEPTUALES Y EL DESARROLLO PROFESIONAL DEL DOCENTE

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Abstract. Los mapas conceptuales son un instrumento que facilita la evaluación diagnóstica de los obstáculos surgidos durante el proceso de enseñanza y aprendizaje del Conocimiento Matemático. Dichos obstáculos se caracterizan por ser conocimientos satisfactorios, en general, durante un tiempo para la resolución de ciertos problemas, fijándose en la mente de los alumnos, pero que posteriormente resultan inadecuados, y es difícil adaptarlo cuando el alumno se enfrenta a nuevos problemas. Los obstáculos se clasifican en epistemológicos, relacionados con el propio concepto; ontogénicos, debidos a las características de los alumnos, y didácticos resultado de las elecciones que guían la intervención. El análisis de los obstáculos patentes en los mapas conceptuales favorecen la regulación del proceso de enseñanza y aprendizaje; siendo una fuente de información que fomenta el desarrollo profesional del docente.

1 Introduction

Este trabajo es parte de un proyecto de investigación orientado a la elaboración de recursos didácticos de diferente naturaleza, adecuados para su integración en el desarrollo de procesos formativos del profesorado, potentes para incidir en su desarrollo profesional. En el hacemos una breve presentación de las posibilidades de este recurso en los procesos de formación y de como se propone su uso.

Los mapas conceptuales son un instrumento que facilita la evaluación formativa del alumnado en diferentes niveles educativos (Moreira y Novak, 1988). Como instrumentos evaluativos son útiles en la detección de errores conceptuales y en la expresión de la evolución, a lo largo del tiempo, del conocimiento de los alumnos (González y Jáuregui, 1992). En el mismo sentido es un instrumento válido para caracterizar el conocimiento previo de los alumnos, el cual interactúa con el conocimiento presentado en la instrucción formal, dando lugar, muchas veces, a un conjunto diverso de aprendizajes no deseados. Aprendizajes que originan errores y estos **errores conceptuales** se constituyen, a veces, en importantes **obstáculos** para el desarrollo del pensamiento creativo y crítico (González, Morón y Novak, 2001).

En el campo de la Educación Matemática se consideran ambas nociones, errores y obstáculos. La noción de error presenta diferentes acepciones como *falta de verdad, incorrección por falta de conocimiento, equivocación, desajuste conceptual o moral, sensor de problemas* (De la Torre, 1993). Desde esta perspectiva la noción de error adquiere significado como producto de la propia enseñanza, desarrollada desde presupuestos tradicionales o tecnológicos. En cambio, en un enfoque constructivista y complejo de los procesos de enseñanza y aprendizaje, los alumnos, principales protagonistas del proceso, han de participar en la elaboración de decisiones sobre la reconstrucción de sus concepciones, percepciones, actitudes y sentimientos personales y los errores son simplemente pasos intermedios en su elaboración del conocimiento (Azcárate, Serradó y Cardeñoso, 2004). Errores que en este proceso de reconstrucción de sus ideas, pueden transformase a veces en obstáculos.

La diferencia entre ambas nociones, error y obstáculo, está más asociada a la perspectiva desde la que nos situemos y, por tanto, al modelo de intervención que desarrolle el profesor durante el proceso de enseñanza y permite abrir un nuevo campo de investigación sobre la utilidad de los mapas conceptuales en el análisis de los procesos de intervención y los obstáculos que pueden surgir.

2 Los obstáculos en la construcción del conocimiento matemático

Los obstáculos son conocimientos que han sido, en general, satisfactorios durante un tiempo para la resolución de ciertos problemas, y que por esta razón se fijan en la mente de los alumnos, como ideas útiles. Pero, posteriormente, cuando el alumno se enfrenta a problemas nuevos este conocimiento resulta inadecuado y de difícil adaptación a los nuevos contextos (Socas, 1997). El obstáculo está constituido por un conocimiento de las relaciones, de los métodos de aprendizaje, de las previsiones, de las evidencias, de las consecuencias olvidadas, de las ramificaciones imprevisibles,… que se resistirá a desaparecer, tenderá a estabilizarse, se adaptará localmente en la medida que ha sido útil (Brousseau, 1983). El obstáculo, como conocimiento, es fruto de la interacción del alumno con su medio y, precisamente, con una situación que le produce este conocimiento "interesante". Como tal, un obstáculo tiene significado en un sistema didáctico en que co-existen un alumno, un conocimiento y un medio.

Brousseau (1983), considera que los obstáculos que se presentan en el sistema didáctico pueden tener diferentes orígenes: epistemológico, didáctico u ontogénico. El obstáculo de origen *epistemológico* está intrínsecamente relacionado con el propio concepto. Los obstáculos de origen *ontogénico* son debidos a las características del desarrollo del niño. Los obstáculos de origen *didáctico* son resultado de una opción o de un proyecto del sistema educativo, es decir, de las elecciones didácticas que se hacen al establecer una situación de enseñanza.

El papel del profesor se debe caracterizar por ser un mediador en el proceso de construcción y reconstrucción del conocimiento para que afloren los obstáculos que permitan desarrollar un aprendizaje significativo a los alumnos. Desde esta perspectiva investigativa, los profesores deberían planificar actividades que permitan florecer los obstáculos de los alumnos; pero, a su vez, permitan diagnosticarlos. Desde esta óptica, constructivista, los mapas conceptuales se constituyen como un instrumento o herramienta que favorece ambas finalidades (Costamagna, 2001).

3 Los mapas conceptuales y el análisis de los obstáculos

La presentación de los resultados sobre cómo los mapas conceptuales facilitan el análisis de los obstáculos en la construcción del conocimiento se realiza desde tres perspectivas diferenciadas. En primer lugar, la reflexión teórica del análisis de los obstáculos epistemológicos, ontogénicos y didácticos a los que se enfrenta un alumno al elaborar un mapa conceptual. En segundo lugar, la ejemplificación de los obstáculos mediante la presentación de mapas conceptuales elaborados por alumnos de 4º de matemáticas de Educación Secundaria Obligatoria (16 años), correspondientes al bloque de contenidos de Geometría (Trigonometría, Geometría analítica y de transformaciones). En tercer lugar, el contraste de la información teórica desarrollada a través del análisis de los mapas conceptuales y los resultados sobre las investigaciones en el campo del desarrollo profesional del docente.

3.1 Obstáculos epistemológicos

Los obstáculos epistemológicos están relacionados con los conceptos. Los conceptos, aunque son imágenes mentales que subyacen bajo las palabras o símbolos con los que se expresan regularidades, suelen tener elementos comunes en todas las personas como producto del proceso de enseñanza y aprendizaje, pero, también pueden poseer matices individuales.

El análisis de las particularidades de cada uno de los conceptos introducidos en los mapas conceptuales elaborados por los alumnos, favorece la reflexión sobre los obstáculos en la construcción del conocimiento matemático. En este sentido, se analiza la presentación de tres tipos de obstáculos epistemológicos diferenciados: relacionados con la terminología utilizada en los conceptos que componen el mapa, la diferenciación de dichos conceptos en hechos, términos o resultados, el olvido de ciertos conceptos.

Los obstáculos relacionados con la terminología que utiliza el alumno se refieren, al uso de un lenguaje cotidiano para otorgar significado a un concepto científico; como se puede observar en el siguiente ejemplo de mapa conceptual (figura 1).

En el mapa conceptual se observa el uso del término elemento mínimo, sin significado científico, para referirse al conjunto de puntos objeto de la transformación geométrica. El obstáculo epistemológico que identifica las nociones de conjunto de puntos y elemento mínimo puede deberse a la identificación de las figuras objeto de una transformación, y se puede reafirmar al entender como limitado el conjunto de puntos que configuran una figura geométrica.

Los alumnos presentan, también, obstáculos en el uso de la terminología matemática. El lenguaje matemático adquiere la facultad durante el proceso de enseñanza y aprendizaje de facilitar la expresión de los conceptos; pero, se puede configurar en un obstáculo al otorgarle más importancia a la notación que al significado del concepto.

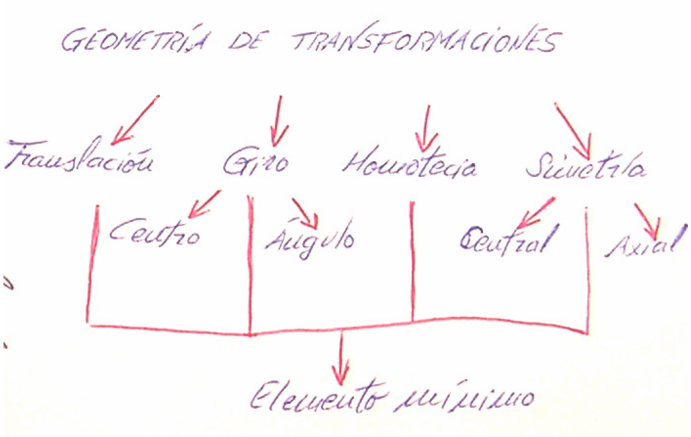

Figura 1: Obstáculo epistemológico asociado a uso de lenguaje cotidiano

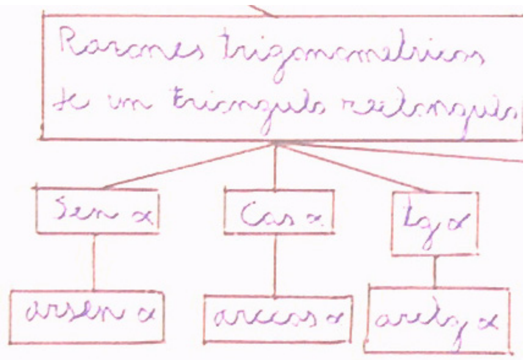

Figura 2: Obstáculo epistemológico en el uso del lenguaje matemático

En el ejemplo de mapa contiguo, se observa el obstáculo que presenta el alumno al utilizar la notación correspondiente al ángulo de las funciones trigonométricas y sus inversas. El alumno utiliza, simultáneamente, la letra griega α para referirse al ángulo, correspondiente según el mapa a un triángulo rectángulo, y para referirse al valor de dicha razón trigonométrica. El obstáculo epistemológico no permite al alumno distinguir entre las medidas angulares y las razones, valores numéricos, correspondientes. Este obstáculo plasmado en el mapa, le dificultará la posterior construcción del significado de función trigonométrica y las funciones trigonométricas inversas.

Aunque la notación supone un obstáculo, intenta relacionar las razones trigonométricas para crear una estructura conceptual. La construcción de las estructuras conceptuales matemáticas se debe regir por la lógica interna del área, que debe distinguir entre hechos y resultados. La veracidad de los resultados, como teoremas, proposiciones o corolarios, esta sujeta a ciertas hipótesis, que se configuran como hechos. Para los alumnos esta estructura lógica es un obstáculo, que se observa a partir de no fijar correctamente ciertas hipótesis para los resultados.

Del análisis del mapa contiguo se puede desprender que el alumno intenta relacionar los conceptos de catetos, hipotenusa, triángulos con el resultado correspondiente al Teorema de Pitágoras. Se observa en esta relación que no tiene en consideración que los triángulos deben ser rectángulos, para que la hipótesis sea cierta y se cumpla el Teorema de Pitágoras.

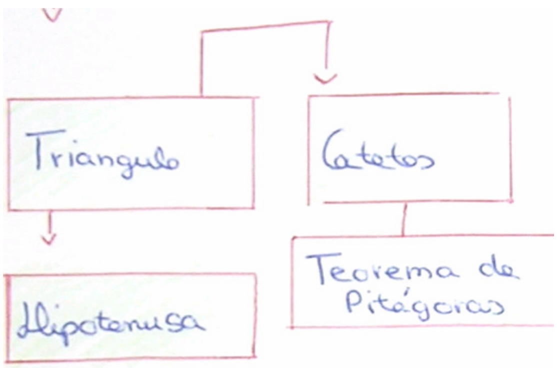

Figura 3: Obstáculo epistemológico en el desarrollo de la estructura lógica matemática

Otro obstáculo epistemológico al que se enfrenta el alumnado, es el intento de relacionar un concepto con una estructura conceptual sin ser capaz de establecer dicho enlace. Las investigaciones sobre mapas conceptuales que el alumno no ha realizado un aprendizaje significativo de dicha noción, siendo un obstáculo al construir nuevos conceptos que dependan de éste.

En el mapa, se puede observar como el alumno es incapaz de relacionar la noción de vector equipolente con la noción de vector. Este obstáculo se refiere a la incapacidad del alumno de generalizar la noción de vector, estableciendo una clase de equivalencia. Dicho obstáculo puede obstaculizar la posterior comprensión del significado de rectas paralelas, vectores linealmente dependientes, espacio vectorial.

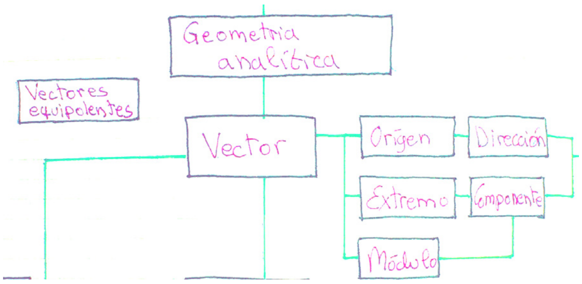

Figura 4: Obstáculo epistemológico debido a la falta de enlace para crear una estructura conceptual

Los obstáculos epistemológicos presentados se refieren a tres aspectos diferenciados. En primer lugar, a los obstáculos que manifiestan los alumnos al utilizar el lenguaje cotidiano como lenguaje matemático, y al uso de la terminología y notación matemática. En segundo lugar, al obstáculo que surge al intentar crear estructuras conceptuales acordes con la estructura lógica que guía la construcción del conocimiento matemático. En tercer lugar, los obstáculos que surgen al no poder relacionar un concepto con una estructura conceptual, que impide que el alumno generalice dicha noción.

Las dificultades de los alumnos para integrar un cierto concepto en una estructura conceptual y generalizar dicha situación se pueden considerar, también, como obstáculos ontogénicos.

3.2 Obstáculos ontogénicos

Los obstáculos ontogénicos son debidos a las características evolutivas del niño y, en particular, a la madurez en el desarrollo de capacidades. Este tipo de obstáculos puede analizarse a partir del estudio de las relaciones que se establecen y las palabras enlace que se introducen en los mapas conceptuales (Serradó, Cardeñoso y Azcárate, 2004). Se valoran los obstáculos que surgen en el desarrollo de capacidades como la generalización, clasificación, planificación o transferencia a otros contextos.

La falta de madurez en la clasificación de los conceptos puede ser un obstáculo para la construcción de los mapas conceptuales. Pero, a su vez, dicho obstáculo se refleja en los mapas mediante una falta de jerarquización de los conceptos que configuran una estructura conceptual. Ante el obstáculo del alumno y la imposibilidad de jerarquizar los conceptos puede tender a dos situaciones diferentes. El alumno puede incluir todos los conceptos en una misma categoría sin distinguirlos, o situarlos en un mismo nivel jerárquico.

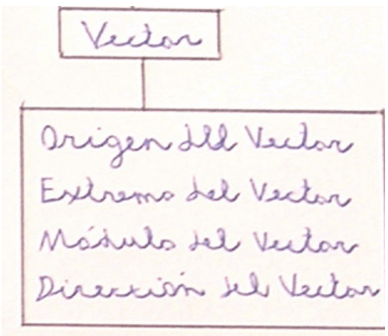

Figura 5: Obstáculo ontogénico

Si el alumno sitúa todos los conceptos relacionados en una misma categoría, refleja la incapacidad de distinguir entre hechos, propiedades y resultados asociados. Dicho obstáculo se podrá observar cuando el alumno realice otras actividades de síntesis de contenidos, como resúmenes, esquemas.

En el extracto de mapa de la figura 5, se observa como el alumno incorpora en una misma categoría los conceptos de origen, extremo, módulo y dirección, sin clasificarlos según si se refieren a las coordenadas posicionales correspondientes de unos ejes de coordenadas de un vector fijo, o a las propiedades físicas que indican la longitud, dirección y sentido del vector. El alumno puede presentar dificultades para obtener la dirección y módulo a partir de las coordenadas, o viceversa.

El alumno puede presentar todos estos conceptos en un mismo nivel de jerarquía, sin distinguir las propiedades analíticas de las físicas, como se puede observar en el siguiente mapa conceptual. El alumno introduce en un mismo nivel jerárquico los conceptos de componentes del vector, con las coordenadas de origen y extremo del mismo, el módulo y dirección. La identificación sin clasificar de estos elementos puede ser un obstáculo para distinguir entre vectores libres y vectores fijos; y el establecimiento de una clase de equivalencia asociada a la equipolencia de vectores. Refleja en el mapa el intento de introducir la clase de equivalencia de los vectores equipolentes a partir de establecer enlaces entre módulo, dirección y componentes.

El análisis de los enlaces y la estructura jerárquica de todo un mapa conceptual o de un extracto del mismo, permite analizar y reflexionar sobre los obstáculos que presenta el alumno para transferir el conocimiento de un contexto a otro. Se presentan dos obstáculos asociados a la transferencia de los conceptos a nivel disciplinar e interdisciplinar.

Si un alumno no introduce enlaces entre conceptos relacionados entre sí, indica el obstáculo que presenta para transferir las propiedades de unos conceptos a otros. En el caso particular de las ejemplificaciones de los mapas que se introducen, los alumnos deben relacionar los conceptos de las unidades de trigonometría, geometría analítica y geometría de transformaciones. Un alumno que presente una estructura jerárquica que no relacione los conceptos de las tres unidades, presenta un obstáculo asociado a la transferencia de los conocimientos geométricos y trigonométricos.

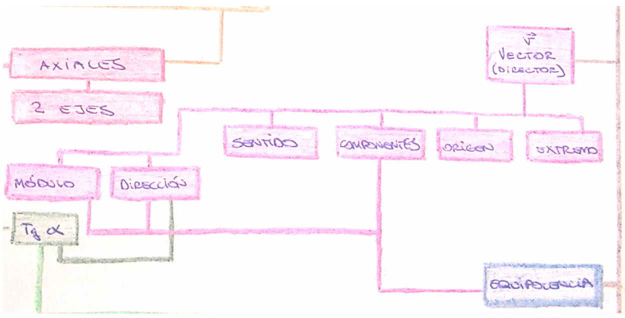

Figura 6: Obstáculo ontogénico

En el mapa se observa que el alumno no relaciona los conceptos trigonométricos con los conceptos geométricos. En particular, no relaciona la tangente y arctangente con la dirección. El alumno presentará un obstáculo cuando deba calcular la dirección de un vector conocidas sus componentes al no relacionar los conceptos de ambas unidades.

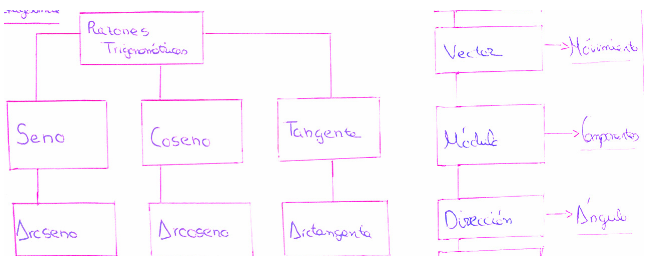

Figura 7: Obstáculo ontogénico, falta de transferencia

Además, el alumno puede presentar un obstáculo al tener que transferir estos conocimientos a otras disciplinas como la Tecnología o la Física. La falta de conexión entre los conceptos trigonométricos y geométricos, le dificultará la comprensión de nociones como fuerza, dirección de un movimiento, velocidad y/o aceleración.

La dificultad en la transferencia de los conceptos disciplinares e interdisciplinares será un obstáculo para la planificación y resolución de ejercicios y problemas. El alumno presentará obstáculos al ejecutar un plan de resolución que implique la aplicación y relación de diferentes conceptos, procedimientos, resultados. En cambio, si el alumno al elaborar el mapa conceptual es capaz de establecer dichos enlaces y proveerlos de proposiciones, está desarrollando nuevas destrezas y estrategias de resolución que le favorecerán la transferencia de los conocimientos en la misma disciplina o en otras disciplinas.

Este obstáculo puede deberse a la propuesta de intervención realizada por el profesor que no facilita que el alumno reflexione sobre las relaciones entre los conceptos, sin favorecer un aprendizaje significativo, sino reforzando un aprendizaje memorístico. En este caso, deberíamos hablar de un obstáculo didáctico.

3.3 Obstáculos didácticos

Los obstáculos didácticos son resultado de una opción o de un proyecto del sistema educativo, es decir, de las elecciones didácticas que se hacen al establecer una situación de enseñanza. Dichas elecciones didácticas se sustentan en las concepciones epistemológicas (positivistas, relativistas o constructivistas del profesor) y las concepciones sobre cómo se aprende. Aunque la elaboración de un mapa conceptual, favorece que el alumno "aprenda a aprender"; relacionando los conceptos de forma significativa, los mapas ya elaborados pueden reflejar un proceso de enseñanza y aprendizaje basado en la memorización de los conceptos. Los mapas se constituyen de esta forma como un instrumento que permite analizar el desarrollo del proceso de enseñanza y aprendizaje, y los posibles obstáculos didácticos que han surgido durante este desarrollo. Los obstáculos didácticos se pueden analizar al contrastar varios mapas conceptuales. El contraste de los mapas conceptuales debe referirse a los conceptos no incluidos, las relaciones y enlaces establecidos, y a la estructura jerárquica.

Si en el contraste de la mayoría de los mapas conceptuales de los alumnos de un grupo clase se observa que falta un concepto, indicaría que estos alumnos no han realizado un aprendizaje significativo ni memorístico del mismo. Esta falta de conocimiento, obstáculo didáctico, podría deberse a que el proceso de enseñanza y aprendizaje desarrollado no ha permitido que el alumno relacionase el concepto con conocimientos previos, que el profesor intentase relacionar dicho concepto con conocimientos previos erróneos, que el profesor y/o alumnos no profundizasen en las propiedades y resultados asociados a dicho concepto, que los alumnos lo considerasen irrelevante para aprendizajes posteriores. Si en el contraste de los mapas conceptuales de los alumnos se observa que faltan proposiciones que establezcan el significado de los enlaces, podría indicar que el profesor promueve un aprendizaje memorístico sin reflexión sobre como se construyen las estructuras conceptuales, o que el profesor no indica la necesidad de introducir dichos enlaces. En las ejemplificaciones que hemos presentado con anterioridad, nos encontramos en este segundo caso.

El profesor promueve un proceso de aprendizaje de elaboración de mapas conceptuales en que primero solicita a los alumnos que se fijen en las relaciones y los enlaces, y no en las proposiciones.

Esta propuesta favorece la aparición de un obstáculo didáctico asociado a la falta de reflexión por parte de los alumnos sobre cómo se relacionan los conceptos para construir una estructura conceptual. No significa que los alumnos, por criterio propio, no consideren la necesidad de establecer proposiciones aclaratorias de los significados plasmados en los mapas conceptuales.

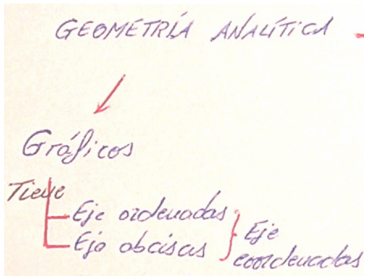

Figura 8: Obstáculo didáctico

El contraste de los mapas conceptuales para analizar su estructura jerárquica, también favorece el análisis de los obstáculos didácticos que han surgido durante el proceso. Mapas conceptuales con una estructura jerárquica muy parecida, pueden ser un reflejo de la estructura lineal y jerarquizada de presentación de los contenidos por parte del profesor, basada en explicaciones que no favorezcan la reflexión individual por parte de los alumnos de las relaciones que se establecen entre los conceptos. En este caso, el alumno presentará seguramente en su mapa conceptual obstáculos ontogénicos y epistemológicos, como los mencionados con anterioridad. Dichos obstáculos no serán fruto de la complejidad de la construcción del conocimiento matemático y sus estructuras lógicas, o del desarrollo del alumno, sino que serán debidos a la propuesta didáctica; estableciéndose como obstáculos didácticos.

El profesor, al valorar la incidencia de dichos obstáculos didácticos, evalúa el proceso de enseñanza y aprendizaje, y su propia práctica educativa. En este sentido, los mapas conceptuales son un instrumento que favorece la evaluación de los procesos de enseñanza y aprendizaje, y la valoración y reflexión sobre las prácticas educativas y los procesos de intervención. La reflexión sobre la información obtenida de los mapas conceptuales favorece la regulación del proceso de enseñanza y aprendizaje; y facilita el desarrollo profesional del docente.

4 Los mapas conceptuales y el desarrollo profesional del docente

Desde una perspectiva innovadora e investigativa, los mapas conceptuales son una fuente de información para que el profesor pueda regular el proceso de enseñanza y aprendizaje (Azcárate, Serradó y Cardeñoso, 2004). Dicha regulación se realiza desde dos perspectivas diferenciadas que se refieren a una intervención directa con un alumno, o un cambio más generalizado en el proceso de enseñanza y aprendizaje.

Desde la perspectiva de la regulación de la intervención directa con uno o varios alumnos, los mapas conceptuales informan sobre las necesidades de refuerzo o profundización en los conceptos desarrollados. Si el mapa conceptual de un alumno presenta obstáculos epistemológicos asociados a un uso coloquial del lenguaje matemático o una terminología inadecuada o obstáculos ontogénicos debidos a la falta de madurez en el desarrollo de capacidades, debería regularse el proceso de enseñanza y aprendizaje de dicho alumno mediante actividades de refuerzo. Dichas actividades de refuerzo deberían facilitar el desarrollo de capacidades como la clasificación, a partir del análisis de las propiedades de los conceptos y de los resultados que se desprenden de los mismos.

En cambio, si el mapa conceptual del alumno presentase obstáculos ontogénicos debidos a la falta de transferencia del conocimiento a otros contextos, detectados a partir de la falta de enlaces y proposiciones, debería regularse el proceso de enseñanza y aprendizaje de dos formas diferenciadas. En primer lugar, mediando para que el alumno estableciese dichas relaciones en el mapa conceptual que estuviese planteando. En segundo lugar, proponiéndole al alumno actividades de profundización sobre las propiedades de los conceptos; favoreciendo la construcción de estructuras conceptuales complejas. En tercer lugar, proponiéndole a los alumnos la resolución de problemas que favorezcan la generalización y validación de las propiedades de ciertos conceptos.

Desde la perspectiva de la regulación del proceso de enseñanza y aprendizaje, los mapas conceptuales son una fuente de información sobre los obstáculos didácticos que surgen durante el desarrollo del mismo. La superación de dichos obstáculos necesita de la reflexión sobre las necesidades de cambio en los procesos de enseñanza y aprendizaje planteados, y en la misma práctica educativa. Dichos cambios pueden surgir del contraste de la información obtenida en los mapas con la información presentada en artículos de innovación o investigación, congresos o jornadas, cursos y seminarios. En este caso, los mapas conceptuales ya no serán únicamente una fuente de información, sino que se convertirán en una fuente de conocimiento que favorecerá el desarrollo profesional del docente (Serradó, 2003).

5 Resumen

El mapa conceptual final (Figura 9) resume los conceptos introducidos en este artículo sobre el uso de los mapas conceptuales en la detección y regulación de los obstáculos en el proceso de enseñanza y aprendizaje.

6 Agradecimientos

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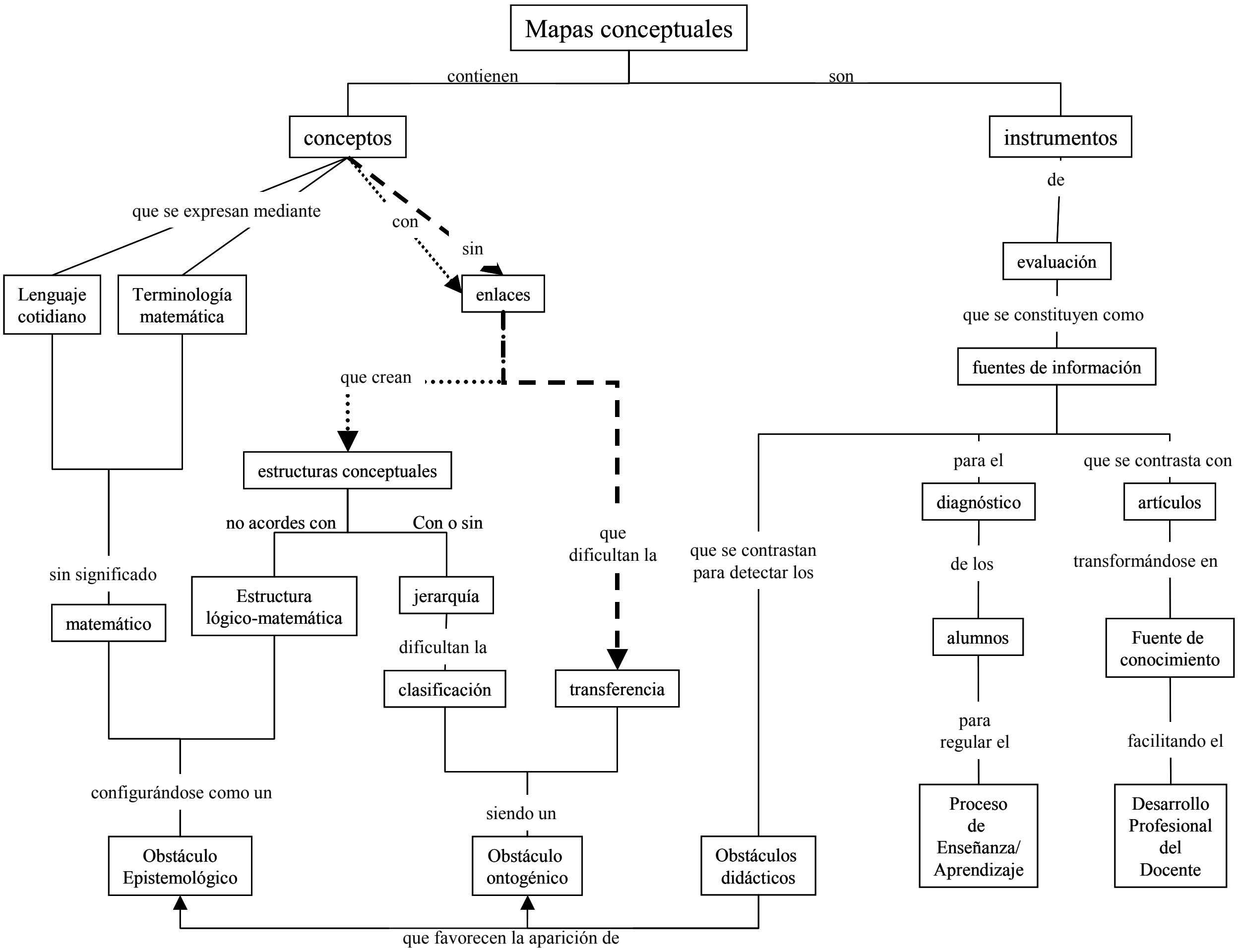

Figura 9: Mapa resumen del artículo

Concept Maps: Theory, Methodology, Technology
Proc. of the First Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

THE CONTRIBUTION OF CONCEPT MAPS TO LOLA – THE ON-LINE LEARNING LAB

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Abstract The need for continuous learning and professional-improvement has never been so strong. Driven by the process of economic development and its social and cultural consequences, pedagogy has been trying to encourage the teaching community to react to the demands and changes of the market, its products and processes. From this world perspective of constant changes due to the globalisation and technological evolution, comes one of the greatest challenges to education: the access to continuous learning, made easier to all segments of society, by the development of a new and creative model which answers to the needs of this society where knowledge ages in an accelerated manner and the production and circulation of information grows by the minute. On-line education becomes a possible alternative to address this issue as it makes use of a technology (the Internet) that allows the reaching of resources that were, up to now, unimaginable. With the objective of overcoming the learning/teaching model of reproduction and accumulation of knowledge, LOLA – The On-line Learning Lab was created in 2002. LOLA, product of TORRES´ doctorate dissertation, was awarded 1st place prize by the Brazilian Association on Distance Learning and the Brazilian telephone communications company EMBRATEL in the category Research. Its proposal is now being augmented by MARRIOTT with the inclusion of the creation of Concept Maps (CM) as both a reading and writing technique. Based on Ausubel's meaningful learning theory, it promotes - at the same time - the activity of both sides of the brain, the analytical/rational and the creative/intuitive, and the construction and the interpretation of its representation promote levels of cognition and communication of the highest levels. In this article, you will learn briefly about the activities developed by LOLA and will be shown how CM was incorporated into this methodology with a class of EFL students giving birth to "LAPLI – The Language Learning Lab – a methodological proposal for a hybrid course in a virtual environment".

1 Introduction

The world development model has been suffering profound alterations due to the process of globalisation of the economy and every transformational movement suggests processes of technological transition. Both developing and developed countries have been seeking to enable their people so that they can react to the demands and changes of the market, its products, and processes.

KENNEDY stresses this understanding, saying that "societies must take the challenge to prepare for the XXI century seriously, when competitiveness becomes the number one factor. An economy that is less and less able to follow the new technologies and to prepare its people, which has slow (or negative) growth rate and stable or falling per capita income while the demographic changes create new social demands, will be in worse conditions as compared to another one that is competitive and adaptable" (KENNEDY, 1993, p.395).

Every professional needs and has the right to continue his / her process of education, keeping him / herself up-to-date, as now the knowledge acquired at school quickly becomes insufficient and obsolete. The meaningful appropriation of the existing information and production of new knowledge to meet the demands of environments that renew and prepare themselves to the future, leads BARCIA (2002, p.A12) to defend distance education as one of the most efficient answers for constant updating, a fundamental factor for economic development. In distance-learning professional improvement, the ability to read, to understand, and to produce new texts becomes a need in the building of knowledge in all areas of instruction.

"The On-line Learning Lab" LOLA was created to propose an answer to the demands of this new knowledge society and to overcome the models of accumulation and reproduction of information.

2 The activities developed in LOLA

The goal of "The On-line Learning Lab" is to create opportunities for collaborative learning. In LOLA, the students (who work individually, in subgroups and in the larger group) collectively construct their knowledge by a constant exchange of information and points of view, by asking and answering questions, and by solving and evaluating problems.

Collaboration between pairs allows for a unique and coherent production from the larger group, contributions coming from the activities of sub-groups as well as individuals, as all of them are shared by all the members of the class by the publication of the activities.

These activities of LOLA both give sense to the groups work and at the same time make it dynamic. It is during the management of these activities that the members of the groups organise and interact between themselves, share roles, discuss ideas and positions, define sub-tasks; the whole proposal is elaborated, defined and negotiated collectively.

In LOLA, the pedagogical strategies are centred in the construction of knowledge and the collaboration between pairs or groups. This collaboration does not envisage a standardisation. It respects the students' individual identities because by sharing their different views they produce and grow together.

LOLA's projection is made by an adaptation of the methodological approach created by BOCHNIAK (1998, p.45 and following), whose activities consolidate the strategy of her Learning Lab and her doctorate. This developed the "Research Pedagogy" that enables students, research teachers and schools to develop a critical learning philosophy so much in demand in today's society. This pedagogy is based on three principles that are: to question the existing knowledge, answer these questions, and evaluate – not the content of the questions and answers but the activities of questioning, answering and even evaluating.

In 2002, the "Research Pedagogy" was complemented by TORRES with activities made possible by the use of technology: links, commented reading and group article, generating "The On-line Learning Lab" - LOLA. It is LOLA's activities, presented below, that allow the person to experience that rapture that is so much needed in the construction of knowledge.

2.1 The "Questioning" Activity

The questioning of the existing knowledge implies in elaborating questions, related to the issues tackled in the course/discipline. These questions are published on-line, always trying to go beyond the reproduction of the existing knowledge. For this purpose, we suggest that students avoid formulating questions that are merely conceptual (using question words like "what", "where", "when"), as they do not lead to a reflexive activity and consequently, do not prepare each other to be a researcher. What we try to demonstrate by this activity is that questions that lead to interpretation (using "why" and "how"), summary, analysis, comparison and application, develop the attitude of research in both student and teacher.

2.2 *The "Answering" Activity*

This activity involves the exercise of answering the questions formulated and published on-line by the students. As in the Questioning Activity, this activity is sometimes performed in groups, sometimes individually, to allow the student to experience the two situations, as they are completely different and equally enriching. When students work individually, they follow their own criteria. When they work in groups, they need to share their choice and negotiate meaning with the other members, thus practice their social skills.

In this exercise, two assumptions from Montessori´s Scientific Pedagogy are clear and interrelated: the assumptions of free choice and freedom with responsibility. In other words, students are free to choose which questions they will answer. However, they must answer the number of questions pre-established by the teacher.

2.3 The "Evaluating" Activity

The evaluation of the questioning, answering and evaluating procedures implies the development of an evaluation which focuses on the process. This activity is always developed in the big group, be it face-to-face, via videoconferencing or even by *Chat*, following that which was already planned with the group. This process of evaluating always occurs after the questioning and answering activities, developed individually or in groups. The focus here is on the evaluation of the process, not of the product.

2.4 The "Commenting on Links" Activity

The activity "commenting on links" involves the exercise of searching the Internet for texts, articles, information and then, publishing them with a comment, thus allowing the whole class to have access to different views of the same theme. This activity promotes the active construction of thought and the development of the students' intellectual autonomy by the questioning and re-elaborating on existing knowledge, ensuring that they are able to produce knowledge. In this LOLA activity, once again the focus is not on the teacher but it is directed towards the group, who is made responsible for choosing the content to be discussed. In the traditional school, it is the teacher who selects the scientific truth to be presented to the students who then are expected to memorize what is presented. In the On-line Lab, the content is selected for students by students, who perform an active, collaborative, and reflexive role in the process of knowledge construction.

2.5 The "Commented Reading" Activity

In this activity, students discuss in groups about texts selected by the teacher. Each group is responsible for reading one text, which is discussed via Chat. After the discussion, one group has to elaborate and publish a few notes about the text, which can then receive comments from the other groups. In this collective process of critical analysis of the contents of the text, students exercise the management of heterogeneity (TORRES, 2002).

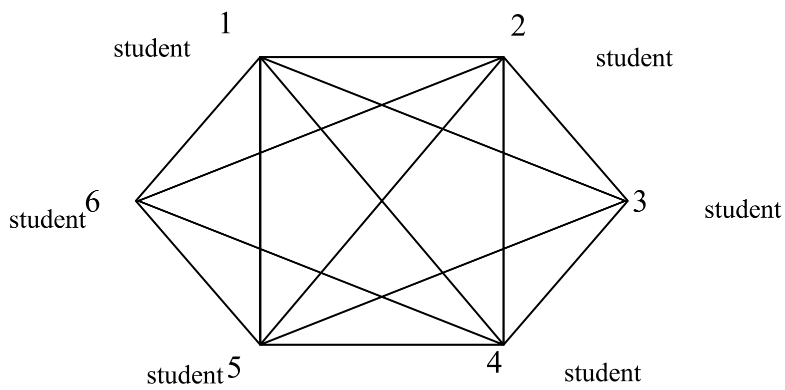
2.6 The "Production of Group Article"

The group article is the exercise of constructing a text about a theme related to their course/discipline and publishing it in the virtual environment. In this exercise, the individual and the group mix all the time. The students' personal universe also merges and a new universe is discovered by the group within LOLA.

In the first part of the exercise, students exchange ideas in their group in order to choose the theme they will be writing about. This negotiation happens by Chat or e-mail, i.e., in a synchronous or asynchronous way, depending on the means they choose to communicate. The members of the group have to overcome difficulties, conflicts, resistance and communication misunderstandings to produce knowledge collectively.

In the second part, students start writing the article. In this process, each member of the group writes his/her contributions, which are forwarded to the other members, who complement, reject, or add ideas. It is in this dialectical educational process, in which all members communicate with each other and act upon the text, that knowledge is produced.

It is possible to represent the dialogue for the construction of the text between the members of the group by the following diagram:



Each member of the group can interact with any other member, forming a communications network. All members of the group perform the role of writer, researcher, editor and critic (reviewer).

LOLA, described above, now receives contributions from MARRIOTT among which we highlight, in this article, the activity of building concept maps presented below.

3 Concept Maps

The use of Concept Maps (CM) is a powerful learning technique, which is being utilized by many universities and organizations worldwide. It promotes meaningful learning and its benefit and use is being studied and stimulated in Brazil by universities like PUCRS, UFRGS, UFSC and PUCPR.

Including pictures or not, concepts are written in boxes which are organized in a hierarchical form – from top to bottom or from the centre to the sides – and are linked to each other by lines which include linkage words (like prepositions, verbs, linking words) that express the relationship between these concepts.

CM is based on Ausubel and Novak's Meaningful Learning Theory (1963) and, as explained by Souza, "Meaningful Learning happens when new information is assimilated by a deliberate effort from the learner's part in linking the new concept to relevant concepts or propositions already existent in his cognitive structure." (SOUZA, 2003, translated by this author). In other words, the learner must wish to acquire new knowledge to be able to anchor it to previously assimilated concepts. By constructing maps, individuals use both sides of the brain (the analytical and the creative) at the same time, in an efficient way as they provide both a general and a detailed view of the subject being studied and encourage the solution of problems by new and creative ways (BUZAN, 2003).

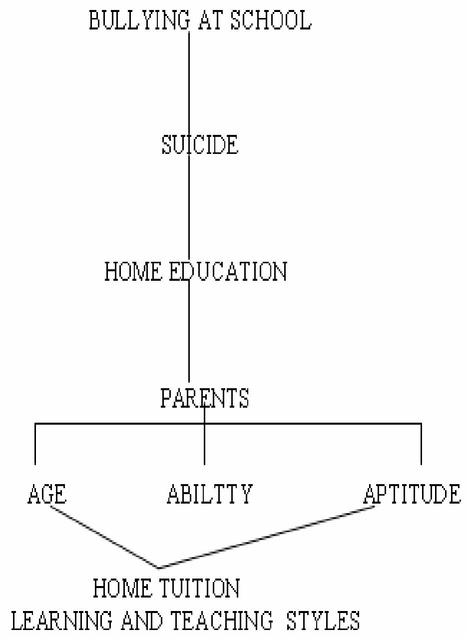
This is an interesting technique to use with mixed ability groups. Students who do not have much knowledge about the subject being studied or whose reading text is in a foreign language of which they have low-intermediate knowledge of, will tend to have more difficulty and therefore take longer to produce their maps which will be, in general, simpler, with fewer concepts and details, and fewer connections between the concepts. On the other hand, students who are more knowledgeable about the subject being discussed and are more proficient in the language being studied, produce more detailed maps, establishing more interconnections between the concepts and anchoring new propositions to previously acquired ones.

4 Concept Maps with LOLA in ELT

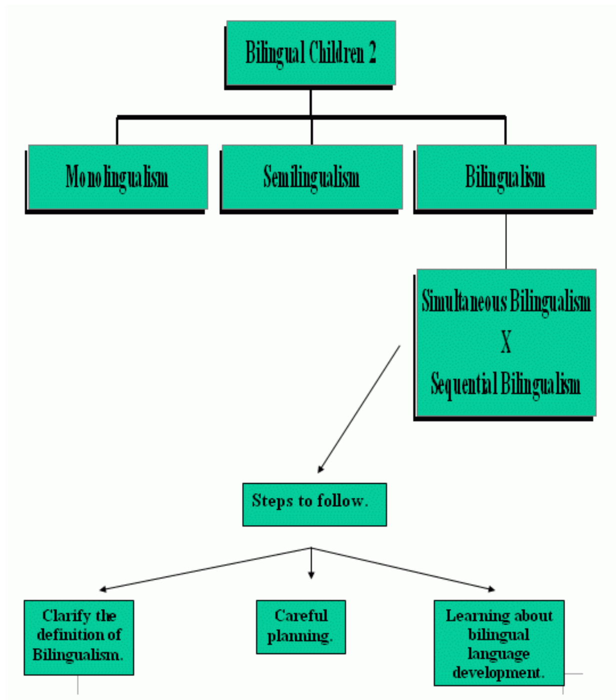
This experiment was developed with a class of university students taking English Language Pre-Intermediate II in the Languages Portuguese / English Course at the Catholic University in Curitiba, Brazil (PUCPR) from August to December 2003. The aim of the project was to develop English reading and writing skills in EFL with High-Intermediate level students using CM and the LOLA methodology in a hybrid course (50%-50%).

After inserting a link about a subject of their interest from the Languages Course (subjects chosen included "Educating Children with Autism", "Bilingual Children" and "Teaching English with Technology") in the "Commenting on Links" activity, students chose one of those texts / articles / links to work on collaboratively, either individually or in groups, and developed the activities of "Questioning", "Answering" and the "Creation of a Concept Map". In the F2F (face-to-face) class, students were introduced to Concept Mapping (its benefits, uses and how to create them) by a PowerPoint presentation elaborated by the teacher, and in the following class – a distance learning class – students consulted sites on CM on the Internet and could download the PowerPoint presentation if they felt the need to do so. When they felt ready, they started producing the CM. These students had three challenges: to learn how to create the CM, to understand how to build a map as part of a hybrid course, and to create it as part of a collaborative activity, i.e., to help their colleague understand their chosen text. The maps were created using the tools available in the software Word, posing another challenge to them as it is not a software dedicated to creating concept maps like CmapTools. Their work is published on-line, in Eureka, PUCPR's virtual learning environment.

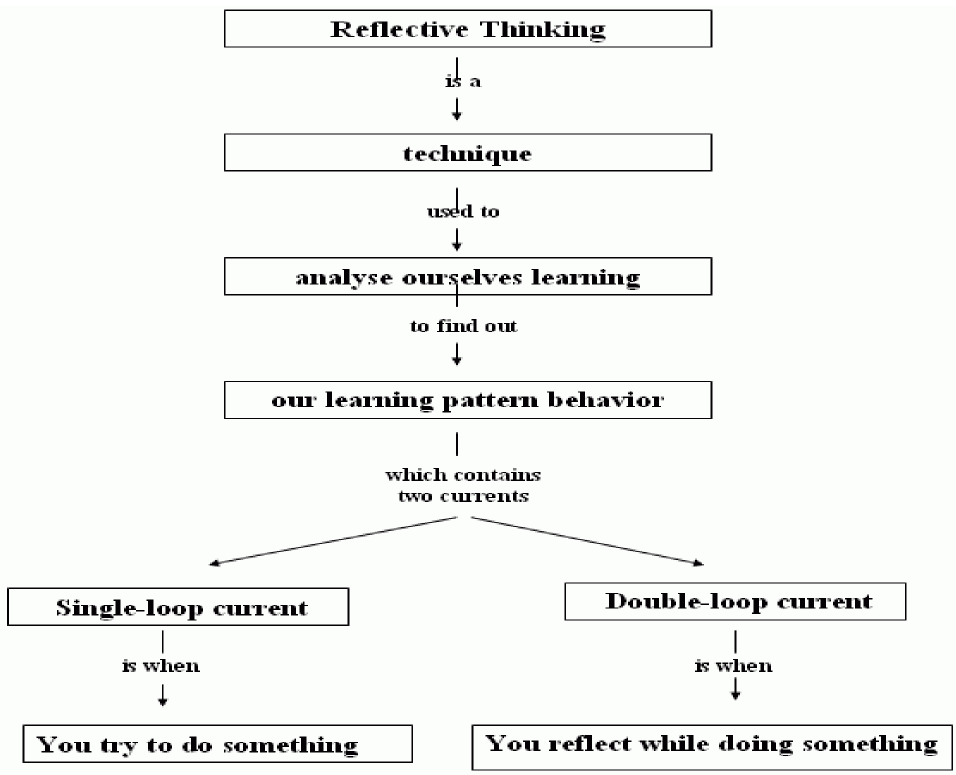
Below you will find examples of students' work from each of the three cycles of activities we had in that course.



Student 12 – cycle 1



Students 6, 16 & 19 – cycle 2



Student 19 – cycle 3

In the maps shown above, we can clearly notice the students' development in their understanding in how to make a CM: in the second map, the concepts appear in boxes and in the third one the student has used linkage words. These maps were then reviewed by the students who inserted the links, and were used at the end of the cycle as a plan to write their articles from.

When asked about the usefulness of using concept maps as a reading and writing technique, students had a positive response, as illustrated below (translated by this author):

20/11/2003 17:50:05	Student 12	answer 2	2
They helped me when I needed to review some ideas. I was taken exactly to the part of the text that I needed.			

20/11/2003 20:54:58	Student 8	Answer CM1	2
I like it because it helps us understand linking words and summarize the ideas we want to express.			

20/11/2003 20:57:49	Student 19	CM_answer	2
As this was the first time we used CM, I can say that, at first, it was more of a hinder than of a help. But, as time went on, I got used to it and I learned how to use it. Today, I can say that it helps me understand the subject better and helps me write better as well.			

20/11/2003 20:59:37	Student 13	Answer	2
The construction of maps summarizes the main concepts of the text that we are working on and this helps when we are constructing our own texts.			

20/11/2003 21:12:10	Student 7	Answer_CM2	2
To construct a CM we need to work with the basic ideas of the text and if we need to write from these ideas/concepts we need to relate these key words establishing meaningful relationships between them and even discover new relationships that we might not have realised when we were reading the text but we came across when creating the CM.			

We feel that the incorporation of Concept Maps into LOLA has been very successful and it can positively help the development of students' reading and writing skills.

This methodology of including CM into LOLA forms part of MARRIOTT´s Master's Thesis on Technology in Education entitled "LAPLI – The Language Learning Lab – a methodological proposal for a hybrid course in a virtual environment" (publication due shortly).

5 Summary

The comprehension of what is read is fundamental when one is working with texts in a F2F or distance learning program. The inclusion of the activity to create concept maps into LOLA enriches this methodology as it offers a way to help students understand written texts and write individual and group articles and shows that, although distance learning is a methodological challenge, the possible pedagogical solutions are countless, especially when the aim is to overcome the paradigm of strictly individual work.

The pedagogical approaches that aim to attain Meaningful Learning through socializing encourage a greater exploration of technology mediated resources, specially those that promote the construction of knowledge and soften the physical and time distance that can be felt between interactive learners. So, the construction of knowledge, developed on-line according to the LOLA approach and complemented by the building of concept maps, leads us to a virtual integration, narrowing the gap between the agents in the learning-teaching process by the support given to the pedagogical communication. Some of the major difficulties in distance learning are then overcome: the use of practices that help in the comprehension of texts, the construction of group articles, the bridging of physical gaps between teacher and students, and, in the case of collaborative learning, the physical gap between the students themselves.

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SUBSTANTIVE KNOWLEDGE AND MINDFUL USE OF LOGARITHMS: A CONCEPTUAL ANALYSIS FOR MATHEMATICS EDUCATORS

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Abstract. This study uses concept mapping to investigate the logarithm. Empirical evidence documents the extent to which selected instructors and students command substantive knowledge about logarithms and analyzes their ability to make mindful use of their current understanding. Initial mapping reflects inadequacy and provides the basis for an in-depth search of the cultural and historical context that gave rise to the logarithm concept. The author presents a map that incorporates the essence of the concept from a cultural historical perspective as its central structure. This key ideational relationship, the conceptual cross link between arithmetic and geometric sequences discovered by John Napier, precisely identifies the source of weakness in conceptualization empirically evidenced among faculty and students. The improved map visually provides the understanding necessary for corrective intervention and is the prime reference in the development of a pedagogical approach toward more substantive knowledge and mindful use of the logarithm concept. Study results indicate that concept mapping can provide an epistemological tool for sound curricular and instructional development in mathematics education; one that seeks to locate and build on the essence of conceptual foundations. In a scientific discipline, graphically rendering such substantive cognitive structures maximizes the probability of their mindful use in related mathematical reasoning.

1 Introduction

Mindful use of an important mathematical concept necessitates substantive knowledge, knowledge that extends well beyond the rote acquisition of standard mathematical procedures. Inversely, mindless use usually involves weak or nonexistent conscious awareness of purpose or meaning involved in activity. Langer (1989) suggests that such mindlessness may be rooted in the development of automatic behavior through repetition and practice. Premature cognitive commitment on the part of a learner, a commitment to an early understanding that lacks the full development that can be achieved through thoughtful contemplation and study of the underlying concepts involved from a historical perspective, may also be the cause. Mindlessness can be induced by organizations with an orientation focused on outcomes, with minor attention given to conceptualization and a focused dependency on rote learning.

Substantive knowledge refers to knowledge that reveals the essence of the concept in question. This notion necessarily avoids the misconception that the cultural historical context which gives rise to an idea, especially a mathematical concept, is of little importance in the development of a deep understanding of that idea. On the contrary, substantive knowledge is grounded in such considerations. An intellectual dedication to a continual search for new and deeper understanding, relating new conceptualizations to current knowledge, may be dependent upon the purity of initial substantive knowledge. Subsequent thought and study is then more likely to locate conceptual cross links, and may, over time, lead to the emergence of mental models that reflect the essence of the original idea.

2 Concept Mapping and Historical Research as a Combined Epistemological Tool

Concept mapping is at the heart of this study. Investigations of four types: an historical search, a conceptual analysis, clinical research involving mathematics teachers and their students, and the development of a curricular approach to logarithms that addresses the historical and cultural foundation of this mathematical concept was constructively informed and guided by mapping. The logarithm is a concept whose understanding must be mediated by knowledgeable and skillful instruction to be well understood. Results of the clinical component of the study provide evidence of the need for conceptual intervention through improved curriculum design based on concept mapping and historical research as a combined epistemological tool. This is done in the context of the philosophical and theoretical ideas of Lev Vygotsky (1978) and the notions of concept formation and generalization of V. V. Davydov (1990) applied to the development of theoretical scientific thought.

Historical references to the sixteenth and early seventeenth centuries provide the original view of the logarithm revealed by John Napier. In order to better understand the context that gave rise to his work, an extensive reading of the general history of mathematics was completed, starting in ancient Egypt and tracing the development of computational methods and mathematical thought from Greece to India and its subsequent spread to Europe via Arab merchants in the middle ages. The specifics of Napier's thinking cast in the complementary histories of mathematics and philosophy provide the scientific and philosophical foundations for understanding what a logarithm is, what gave rise to the idea, and gives a sense of the important cultural implications of the discovery**.**

A concept map developed to reveal the discovery of John Napier in its essence provides a surprising consequence with far reaching curricular implications for mathematics educators. The central understanding of the logarithm concept illustrated by this map was compared to those generated from interviews with three faculty members and six of their students and the texts they use as resources. A composite map reflecting all understandings and relationships was also created for purposes of contrasting perceptions. The map further displays traditional instructional content, current curricular focus, and implications for the study of calculus, advanced science, and technology. By means of this composite map, six clinical analysis categories were identified and addressed. Of significance here are the categories of "Conceptual Representation," "Student Competency and Problem Complexity," and "Application and Importance." Findings translated into the development of a significant change in pedagogical approach illustrated in a series of introductory logarithm lessons.

3 Conceptual Analysis From a Cultural Historical Perspective

Scientific ideas are, in the Vygotskian sense, ideas that do not occur spontaneously in the human mind as a result of normal everyday experience but require dedicated theoretical analysis.

> If every object was phenotypically and genotypically equivalent..... then everyday experience would fully suffice to replace scientific analysis. ... real scientific analysis differs radically from subjective, introspective analysis, which by its very nature cannot hope to go beyond pure description. The kind of objective analysis we advocate seeks to lay bare the essence rather than the perceived characteristics of psychological phenomena. (Vygotsky, 1978, p. 63)

Scientific ideas spring from and are mediated by a social, cultural, and historical context. John Napier's definition of a logarithm is just such an idea and provides a generalization worthy of historical exploration using the lens of Ausubel's cognitive learning theory as described by Novak and Gowin (1984). I refer to the notions that cognitive structure is *hierarchically organized,* that this structure is *progressively differentiated*, and that the process of *integrative reconciliation* may yield linkage between concepts providing new propositional meaning. The historical record of Napier's work also reveals strong evidence in support of Vygotsky's thoughts on cultural mediation. Napier's discovery is a perfect example of *integrative reconciliation*. His particular linkage of geometry and arithmetic has impacted the world for nearly four hundred years.

3.1 Historical Foundation

In 1619, John Napier wrote, *Mirifici Logarithmorum Canonis Constructio*, in which he explained his idea of using geometry to improve arithmetical computations. This was the breakthrough that accelerated the discoveries of science and led to the creation of new calculating devices, ultimately leading to modern day electronic calculators and computers.

Seeing there is nothing, right well-beloved students of mathematics, that is so troublesome to mathematical practice, nor doth more molest and hinder calculators, than the multiplication, division, square and cubical extractions of great numbers, which besides the tedious expense of time are for the most part subject to many slippery errors, I began therefore to consider in my mind by what certain and ready art I might remove those hindrances. - John Napier

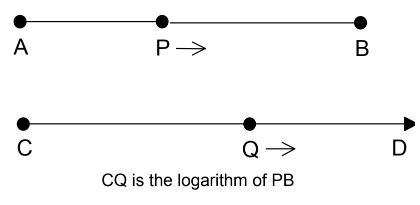

Figure 1. John Napier's development of the logarithm concept.

The account of the mathematical consideration Napier used in defining a logarithm refers to points moving on two different lines (Figure 1). Consider that point P starts at A and moves along segment AB at a speed proportional to its remaining distance from B. Simultaneously, point Q departs from C and moves along ray CD with a constant speed equal to the starting speed of P. Napier called the distance CQ the logarithm of PB. This idea proved to be an important benchmark in the history of mathematical thought, providing a cross link between concepts that immediately accelerated the interests of science and economics.

The genesis of Napier's discovery is situated in Egyptian, Greek, Hindu, and Arabic thought and reflects the influence of the Renaissance on scientific thinking. From the Egyptian papyrus of Ahmes we see work on the reduction of fractions of the form 2/(2n+1) into a sum of fractions with numerators of one, an early form of computational efficiency. As the flow of ideas is transmitted between cultures, the Greeks provide theoretical structure to mathematical thought. Pythagoras establishes the twice split view of mathematics (Figure 2) (Turnbull, 1969) that places arithmetic and geometry on distinctly separate branches. Hindu mathematics, like the Greek, considered arithmetic and geometry as separate categories of mathematics. It is a significant conceptual separation that becomes the focus in the late sixteenth century; ideas actually cross-linked by Napier.

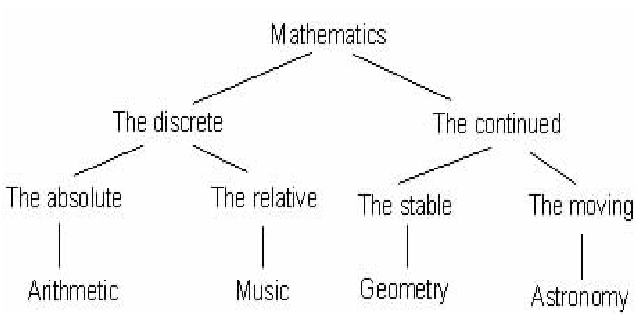

Figure 2. The view of mathematics attributed to Pythagoras.

This historical sampling of mathematical thought reveals the setting, motivation, and approach that made the discovery of logarithms possible. The intent of historical reference is to have a sense of what John Napier knew at the time of his discovery. Access to his understandings sharpens the focus of our own as we consider the true nature of what he revealed to the scientific world. The cultural historical approach to the appropriation of knowledge is dependent on such considerations. Significant is the realization that it is only through this historical lens that the true essence of the scientific thought can be understood. In the case of the logarithm, evidence serves to inform us that, motivated by computational efficiency, Napier provided a theoretical link between the worlds of geometry and arithmetic. This novel generalization provided fertile territory for new development, practical and theoretical.

3.2 Conceptual Essence of the Logarithm Concept from a Cultural-Historical Perspective

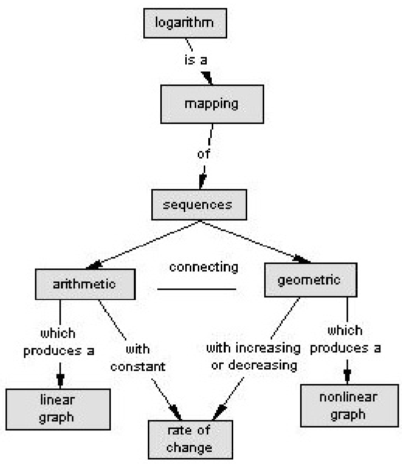

Figure 3. A concept map of logarithm showing the historical conceptual cross link, the genesis of a new mathematical idea.

Based on historical reference, a logarithm is a mapping between number sequences with different types of change rates (Figure 3). The arithmetic sequence has a constant rate of change while the rate of change of the geometric sequence either increases or decreases. It is this connection that accounts for the computational power and efficiency the logarithm provides and justifies the importance of this discovery in the historical account of mathematical development. The map situates the conceptual genesis of a new mathematical idea, a realization of a connection between arithmetic and geometry. This relationship is the substantive understanding that requires mediational attention if students are to make sense of their work with logarithms. The mapping across two previously considered disjoint branches of mathematical thought is the core of the logarithm concept, an idea that became of prime interest with the later discovery of exponents and the emergence of calculus.

3.3 More Fully Developed Concept Map of a Logarithm

As is often the case, theoretical development leads to new technology. The new technology is applied to practical matters and simultaneously enables related theoretical development. The logarithm gave scientists a new conceptualization that proved immensely valuable in their effort to describe properties of the physical world using the language of mathematics. It should be noted here that the theoretical explanation found in the *Mirifici*, though completely consistent with calculus, was written prior to the existence of calculus. Points P and Q, moving along at different rates in figure 1, PB decreasing in geometric progression while CQ increases in arithmetic progression, would necessarily fall in the jurisdiction of the mathematics of change, namely calculus. Napier's geometric representation defined logarithms in kinetic terms and foreshadowed their significance in the development of calculus. Therefore it is not surprising that we find logarithms along side other transcendental functions in every modern calculus text. What you do not find in the *Mirifici* is any mention of logarithms as exponents. Bernoulli and others recognized this connection toward the end of the 17th century. "One of the anomalies in the history of mathematics is that logarithms were discovered before exponents were in use." (Eves, 1969)

In a sense, Figure 3 represents all that was known about logarithms in 1619. Continued mathematical conceptualization provides a concept map of far more extension and depth. The growth of relationships that develop in a scientific discipline rapidly create a complex structure that may mask the purity of the concept at the core.

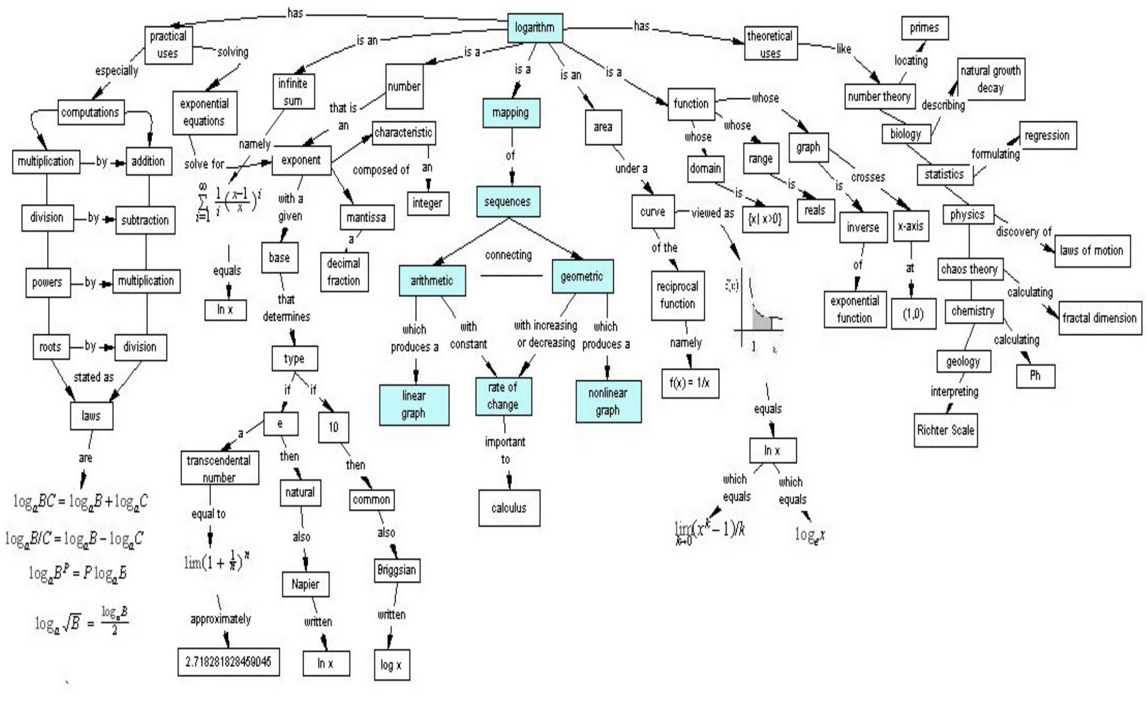

Figure 4. A concept map of logarithm with a cultural historical perspective as its central structure.

Figure 4 incorporates the cultural historical perspective as the central structure of a more detailed map of the logarithm concept. Generally, concepts arranged on the left are more strongly associated with the arithmetic notions and those on the right more geometric in nature. Practical uses appear on the left and theoretical connections on the right. It is interesting to note that the exponent emerges with such prominence in the map even though the concept was unknown when the logarithm relationship was first recognized. The same is true for the calculus related content. It too is well represented in the map though it had not yet been developed. This suggests the importance of cultural historical considerations in curriculum development. The concept exists without reference to these later developments.

The map in Figure 4 clearly reveals the extent of schema development that can arise from a simple consideration of points moving on a line. For the mathematics educator, the map complexity can be problematic if the essence of the concept, represented by the central structure, is missing. Instructionally, the concept loses its original meaning. Practical uses become independent procedures involving symbol manipulation. Theoretical connection becomes impossible, for there is no meaningful cross over access without substantive knowledge. Without conscious conceptual understanding of the essence of a scientific idea, mindful use is impossible.

4 The Problem of Generative Metonymy

Schmittau (2003) has identified the problem of generative metonymy as an impediment to mathematical understanding. Epistemological uncertainty accounts for considerable confusion in mathematical thought and the difficulty of understanding more advanced mathematics. As linguists Lakoff and Johnson (1980, p.39) remind us, "metonymic concepts allow us to conceptualize one thing by means of its relation to something else." This use of language applied to scientific concepts masks the ideational essence and effects how a learner organizes their thoughts around new ideas. Multiple iterations of metonymy can develop completely inadequate conceptualizations leading to a form of intellectual desiccation. For students in this study, the ability to reason mathematically and problem solve with logarithms was minimal. As a result of generative metonymy the concept had lost its genetic meaning.

4.1 Conceptual Representation – the Teachers' View

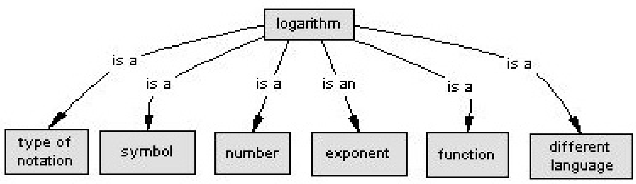

Figure 5. Composite Concept Map of Teachers Characterizations of a Logarithm

Teachers (Figure 5) variously describe a logarithm as: "a number," "a symbol," "a type of notation," "a function," "a different language," and "an exponent." This metonymy makes no mention of the essential characteristic, the mapping between geometric and arithmetic sequences. The primary understanding of teachers in this study is that a logarithm is an exponent. This is a central theme in their efforts to teach students this concept. The awkward and somewhat nebulous statement that a logarithm *is an exponent that you raise the base to to get a number* is often abbreviated to *a logarithm is an exponent.* The statement is highlighted, underlined, and made the key idea in logarithm chapters of each of the twelve textbooks investigated as part of this study. The statement doubly masks the essence of a logarithm and fails to provide the conceptual connection that would make sense of both practical and theoretical applications.

Of related importance are the views of teachers Fred, Maria and Steve. Fred teaches logarithms as a notational convenience. "They [the students] have a hard time with the definition because it's pure notation to them. It's a symbol, $\log_b x$." Maria's students are taught to solve exponential equations using logarithms, a process used as justification for the existence of the logarithmic concept. "The emphasis should be on what a logarithm is. I start with an equation that is impossible to solve without logs, something like $5^x = 112$." Steve relies on the fact that a logarithm is a function. "I like to think of it as a function that returns a number. The log of x is going to give you back a number. What number? It's going to be the exponent, the log always returns an exponent." These statements represent clear evidence of some teachers' admitted algorithmic focus and the superficiality of understandings they present to students. There is little substance compared to the conceptual essence depicted in Figure 3.

4.2 Conceptual Representation – the Students' View

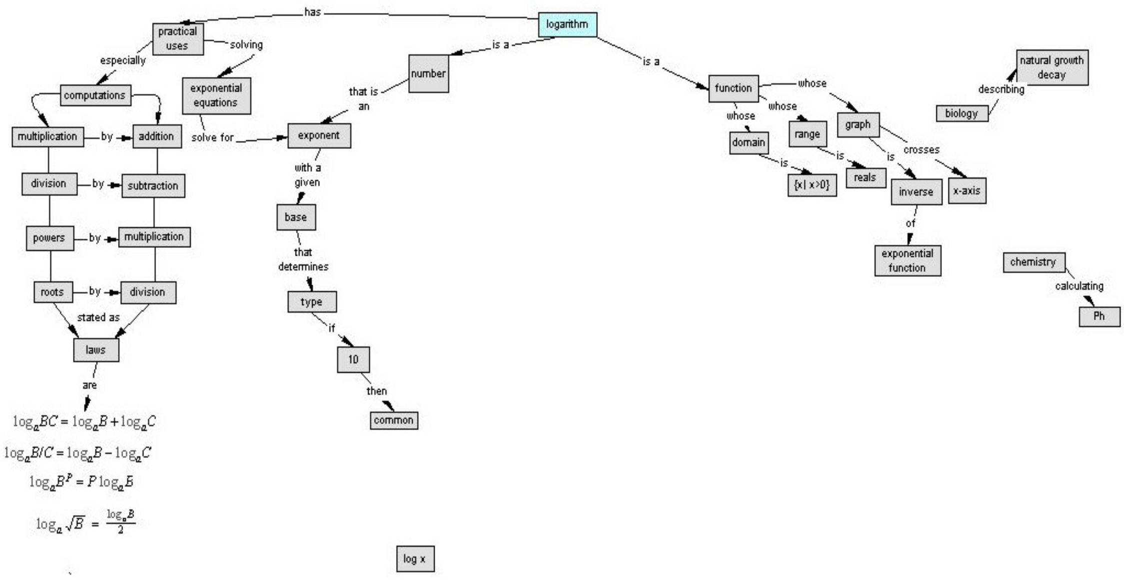

Figure 6. Concept map of logarithm from students' perspective

The map in Figure 6 was created from the map in Figure 4 by removing anything not mentioned by students in six hours of interview. In this sense, the map in Figure 6 represents a composite of student understanding for the logarithm concept. Note that the critical core, the essence of a logarithm, is missing. The laws of logarithms and their use in solving exponential equations remain. Of the scientific applications seen in Figure 4, only pH and natural decay are cited. The student map reveals the limited nature of understanding and accounts for the inadequacy of mathematical reasoning expressed in interviews. How are students to understand the significance of reports of seismographic activity, for example? Will comparisons of 1.1 and 2.2 on the Richter scale be incorrectly interpreted as an earthquake of double intensity, when in fact the increase is tenfold due to the logarithmic nature of the scale? What sense will students make of Mandelbrot's (1977) work on fractals when the formula to determine fractal dimensions depends on logarithms? How will students read with wonder, Bronofsky's (1973) eloquent description of Ludwig Boltzmann's formula S = K log W, entropy is in direct proportion to the logarithm of W, the probability of a given state. It was this formula that settled the theoretical debate over the existence of atoms and made possible current advancements in physics and biology. The student logarithm map revealed in Figure 6 is the direct result of generative metonymy, mediational inadequacy, and is void of conceptual essence. This lack of substantive knowledge makes mindful student use of logarithms unlikely.

Improved conceptual representation can positively impact student problem solving competency and improve their ability to apply their knowledge to related scientific work. It is possible to present the logarithm concept to students in a manner very similar to the geometric rendering of the definition offered by Napier. As Schmittau (1993, p.34) has stated, "pedagogical mediation must facilitate the appropriation of the scientific concept through a mode of presentation that reflects the objective content of the concept in its essential interrelationships." By doing so with logarithms, it may be possible to close the gap of conceptual understanding that is evident among students and similarly reveal the computational consequence that enabled the scientific community. As a result of this study, four mathematics lessons have been created toward that end. The first lesson addresses the essence and origin of the concept. The second lesson presents the link between the conceptualization of a logarithm as a relation between moving points and the graphical representation of that relation. The third lesson shows the impact of Napier's discovery on computational efficiency and accuracy. The final lesson investigates the use of logarithmic scales in mathematical reasoning. This curricular work in mathematics represents the positive contribution to be made by using concept mapping in conjunction with cultural historical research.

5 Summary

Vygotskian notions on cognitive development direct mathematics educators to identify the essence of concepts to be taught, reflecting with clarity the cultural historical context that produces new mathematical thought. Concept mapping, when combined with historical research, serves as an important epistemological tool that can, at once, render to consciousness the conceptual essence of a mathematical idea, identify for educators substantive focus for curriculum design, and provide pedagogical direction toward the mindful use of learned mathematics on the part of students. Meaningful instruction in mathematics avoids the temptation of a rote learning approach, recognizing that functional efficiency often leads to cognitive deficiency. Complex problem solving depends on the thoughtful application of meaningful mathematical ideas. Concept mapping can instruct and guide mathematics educators toward a pedagogy of significant cognitive consequence.

6 Acknowledgements

My special thanks to Dr. Jean Schmittau for her willingness to share her extensive knowledge of Vygotskian psychology. Her expertise and continued guidance has furthered my conceptual understanding of cultural historical theory and its importance to mathematics education. I would also like to thank the teachers and students who willingly provided the clinical content of the study reported in this paper.

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EXPERT AND STUDENT CONCEPTIONS OF THE DESIGN PROCESS: DEVELOPMENTAL DIFFERENCES WITH IMPLICATIONS FOR EDUCATORS

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Abstract. If educators want students to learn to think like experts, then we need to learn how experts think. In this set of studies, we posed two questions: (1) what is "the wisdom" of engineering design (i.e., what are the key concepts), and (2) how do people at different points of professional development define the engineering design process? Both questions were intended to enhance understanding of and support for students' professional development and conceptual understanding of design. The method of assessment used was concept mapping. A concept map is a spatial representation of ideas and their relationships. Fifteen experts in academe and industry each constructed a map reflecting their understanding of the design process. From those maps, we extracted critical concepts to establish a taxonomy consisting of six broad categories: the design process, motivation for the design, interpersonal skills, technical skills, safety (e.g., regulation, ethics), and marketing. These categories were then used as benchmarks for assessing the development of undergraduates taking a year-long senior design course. Students constructed individual maps at three time points. Analyses revealed that students and experts expressed similar understandings of the importance of interpersonal and technical skills; however, students made consistently fewer references to safety and marketing than did experts. Over time, the expert-student gap closed in two areas: knowledge of the design process and its underlying motivations. In addition to their implications for educators, these findings offer an important avenue for understanding the nature of expertise. That is, they suggest that experts have a more developed understanding of the social context in which a design and designers function. The study's implications for research in concept mapping are also discussed.

1 Introduction

Across a variety of fields research has suggested that the development of expertise involves the acquisition of concepts and an understanding of their abstract relational dimensions [1]. Another hallmark of expertise is the ability to recognize meaningful "chunks" of information [2]. These findings suggest that experts not only know more than novices, they organize and use their knowledge differently from novices. They also support theoretical arguments that people structure their knowledge in propositional representations (i.e., sets of information) [3] and that networked propositions are the bases for human reasoning [4].

Another key feature of expertise is that it is domain-specific. Expertise in one area does not necessarily translate into expertise in another [5, 6]. In this study, we wanted to identify "the wisdom" of expertise in engineering design (i.e., key concepts), and explore whether people's conceptions of the design process differ according to their level of experience and professional development. We had two overarching goals. One goal was to establish a method of assessment that would inform our understanding of expertise in design. A second goal was to use what we learned about how experts think to inform engineering education at the undergraduate level. In other words, if we know the wisdom of design expertise, can we translate that into more meaningful educational experiences?

A significant challenge to researchers interested in the novice-expert shift is establishing valid and reliable ways of capturing and representing what people know, how they apply their skills, and how their performance varies over time and with experience [7, 8, 9, 10]. A variety of methods have been used to explore developmental differences including, asking people to "think aloud" as they engage in problem-solving activities, to critique the solutions of others, and observing problem-solving performance *in situ*.

This work has identified patterns in students' thinking, some of which may interfere with their ability to enter the professional design community. For instance, when asked to define the design process, students often emphasize the role of creativity more than iterative processes such as evaluation and revision; they also appear to design for themselves rather than considering the needs of the user [11]. When solving design problems, less-experienced students often "getting stuck" modeling a single alternative solution rather than considering many alternatives whereas more advanced students advance to later stages of the design process (e.g., decision-making and project realization) [12].

To capture and assess expert and students' conceptual understanding, *and* support student learning we used concept mapping. Elsewhere, we have described how concept maps can be used to assess expert-student differences in the field of biomedical engineering, and to assess the development of students' thinking about the design process [13]. Here, we extend that work by using concept maps to elicit a broader sample of experts' understandings of design and, in turn, create meaningful benchmarks for evaluating students' developing conceptions over time. Our work was intended, in part, to address recent observations that much of the research in expertise focuses on classifying people as novices *or* experts rather than tracking how people develop expertise over time [14]. We were also interested in developing a reliable method for assessing the contents of individuals' maps. Finally, recognizing that helping students become aware of their tacit knowledge frameworks is an important means to enhanced learning [15, 16], we archived students' representations over time, and then asked them to comment on the similarities and differences between their initial and final maps. We also encouraged students to use one of their maps as a study guide for an exam near the end of the first semester.

We posed three questions: (1) What are key concepts in the engineering design process? (2) Are there developmentally related differences in people's conceptions of this process? (3) If so, then what do these differences mean for theoretical understanding of design expertise and for design education? We expected that, relative to students, expert maps would have more accurate propositions, and have more densely networked concept across a wider breadth of categories. Over time, we expected student maps to increase in accuracy and complexity.

2 Methods

Our first goal was to determine how experts define the design process, and establish benchmarks of expertise. This work is described as Study 1. Our second goal was to examine students' definitions relative to those expert benchmarks. Work with students is described as Study 2. We conclude with a comparison of the two groups.

2.1 Study 1: Experts

We began by soliciting participants from academe and industry; the second and fourth authors invited approximately 60 design colleagues to participate via electronic mail. From this pool, 15 experts consented to participate. Ten participants had doctoral degrees, 3 had graduate degrees and 2 had completed undergraduate programs in various engineering disciplines. Participants had an average of 9 years experience in academia, 11 years in industry and 10 years in teaching or supervising design. Nine of the participants had industrial and academic experience. 14 of the participants were male.

Because our experts were located across the globe, orientation procedures and data collection was conducted electronically. Participants were sent an electronic letter that explained the study, described the concept mapping procedure, and provided a web link to a tutorial on how to build a concept map. Experts were asked to respond to the focus question, "What is your current conceptual understanding of what is involved in the biomedical engineering design process?" Once constructed, maps were sent electronically to the first author. Participants also provided basic demographic information, and a brief description of how their map reflected their professional history and understanding of the design process.

2.1.1 Analyses and Results for Experts

All maps were analyzed by the second and fourth authors. Blind to the identity of the map authors, these raters counted the number of concepts and lines in each map. A line:concept ratio was calculated by dividing the number of lines by the number of concepts. Inter-rater reliability on these metrics was acceptable (node, $r = .99$; line, $r = .99$; density, $r = .96$; range = 0 to 1).To evaluate the accuracy of map propositions, we used a modified version of a relational scoring method [17] in which the validity of each map's proposition is evaluated based on the correctness of the linking word. We awarded no points for an invalid or misconceived link; 1/2 point for a partially valid, general or imprecise link; and 1 point for a valid, precise, and clearly stated link. Our two raters had acceptable agreement on the validity ratio of map propositions ($r = .80$, range = 0 to 1).

Expert maps contained an average of 26 concepts ($M = 26.23$, $SD = 15.37$), 33 lines ($M = 32.97$, $SD = 17.78$), and 1 line per concept ($M = 1.31$, $SD = .25$). Variability in these structural elements was considerable (concept, range = 13-60; line, range = 15-75, density, range = 1.04-1.86), prompting us to identify a subset of maps for more intensive analyses. Eight maps were selected on the basis of their general coherence and relatively higher validity scores ($M = .93$, $SD = .03$; range = .88-.97). These maps contained an average of 29 concepts ($M = 29.19$, $SD = 14.06$, range = 16-52), 37 lines ($M = 37.06$, $SD = 14.49$, range = 24-61) and 1 line per node (line:node, $M = 1.35$, $SD = .27$, range = 1.04-1.86).

To identify key concepts in the design process, we wrote each concept contained in each expert's map on a separate index card. This yielded a set of 78 concepts; identically worded concepts were not counted. The first and second authors then sorted these cards based on their conceptual similarity. From this process, 6 categories emerged: the design process (e.g., product definition, prototyping), interpersonal skills, technical background, motivation for the design, marketing and overriding societal concerns (i.e., ethics, regulation). Each concept card was then reviewed with an eye toward eliminating conceptually similar ideas within categories. For example, 'personal skills' and 'communication skills' were collapsed into the single term 'communication skills.' This process yielded a reduced list of 42 concepts. Iteration continued until the full list of concepts was reduced to a set of 27 unique biodesign concepts.

Maps were then examined for references to these 27 concepts. Semantic similarity, not exact terminology was required. For instance, if both technical skills (e.g., "computer programming skills") and technical knowledge (e.g., "biology") were mentioned, then the map received a 100% coverage rating for the category of technical background. If only one of these concepts was represented then a 50% coverage rating was given. Table 1 summarizes descriptive statistics across the six categories. Inter-rater reliability across the 6 categories was acceptable (possible range = 0 – 1; actual range = .78 -.95).

Table 1. Means, standard deviations and ranges for percentage of concept coverage among 8 expert mappings (possible range = 0-1).

	Design process	Interpersonal skills	Technical background	Motivation for design	Marketing	Ethics
M	.40	.29	.44	.42	.35	.46
SD	.19	.33	.40	.22	.30	.29
Actual range	.10-.66	0-.84	0-1	0-.67	0-.67	0-.84

Finally, we examined what experts said their maps represented. One expert noted that his map was "greatly influenced by industry experience in product development," and that it was "based on practical, relevant, important issues and concepts crucial for successful medical device design and successful career paths. It is not based on theory and includes not only technical but related economic and regulatory concepts." Another offered, that "industry considers how the design process interfaces with other organizational components and the skills to successfully manage the design process." Thus, his map was "broader" compared to a "focus on the technical knowledge and skills required to design the device itself." These qualitative comments suggest that experts not only recognize the technical and procedural demands of the design process, they also situate that process in a social context with ethical and financial constraints and opportunities. This is an especially critical finding for engineering educators because it supports arguments that experts not only have extensive domain knowledge, they also understand when and how to use what they know [18].

2.2 Study 2: Students

As part of their course requirements, 51 students enrolled in a capstone design course at Vanderbilt University were asked to construct concept maps focused on the same question given to experts. Complete data was obtained for 32 students (participation rate = 63%). At the opening of the course, students were given a brief orientation to concept mapping and directed to the same web-based tutorial provided to experts. They were then directed to construct a concept map responding the question, "What is your current conceptual understanding of what is involved in the biomedical engineering design process?" The map was to be constructed as a homework assignment. Shortly before the final exam at the end of the fall semester, students constructed a second map focused on this same question. Students were allowed, and encouraged, to use this map as a study guide and final exam "cheat sheet." Students completed a third map at the end of the spring semester, a time coinciding with their presentation of their design project and the composition of a final paper. At this time, we asked students to reflect on and summarize, in writing, how their final map compared to their initial map.

2.2.1 Analyses and Results for Students

Analyses are identical to those described for expert mappings. Inter-rater reliability on these metrics was acceptable (intraclass correlation = .89, range = 0-1). Inter-rater correspondence for the validity of map propositions was also acceptable (intraclass correlation = .77). One-way repeated measures analyses of variance (ANOVA) showed significant linear and quadratic trends for the number of concepts and lines (concepts: linear, $F [1, 31] = 8.20$, $p < .01$; quadratic, $F [1, 31] = 74.58$; lines: linear, $F [1, 31] = 8.05$, $p < .01$; quadratic, $F [1, 31] = 67.19$, $p < .01$). No significant trends were found for density and validity. The average line:concept ratio or network density was consistently low (i.e., almost 1:1); the average validity of map propositions was high (possible range = 0 to 1). Table 2 summarizes descriptive statistics for these dimensions of student maps over time.

Table 2. Means, standard deviations and ranges for the number of concepts and lines, density of network, and proposition validity of student mappings.

	Time 1		Time 2		Time 3	
	M	SD	M	SD	M	SD
Concept	16.47	4.62	34.19	12.34	20.92	9.40
range	*11-34*		*13-54*		*8-54*	
Line	19.58	6.16	39.38	13.99	24.91	11.44
range	*13-39*		*17.5-70*		*8-57*	
Density	1.20	.22	1.18	.20	1.21	.23
range	*.93-2.11*		*.94-1.63*		*.92-1.97*	
Validity ratio	.93	.14	.88	.19	.88	.22
range	*.49-1.00*		*.24-1.00*		*.25-1.00*	

Significant increases in the number of concepts and lines suggested that students gained conceptual knowledge about the design process during the first semester. However, stability in the validity of map propositions suggested that students did not necessarily develop a deeper understanding of associations among concepts. While we expected a steady increase in these map elements, we found significant quadratic trends. We suspect the increases observed at Time 2 stem from the fact that students constructed their maps as a study aid for the final exam.

Our two raters also examined student maps for the presence and absence of the 27 key concepts. The percentage of semantically similar concepts represented in the student map or "coverage" of the domain taxonomy was calculated. One-way repeated measures ANOVAs showed linear trends for the categories of the design process, interpersonal skills, genesis of the design, and ethics. A quadratic trend was also found for the design process and for ethics.

Table 3. Results of one-way repeated measures ANOVA testing trends for time in categorical content of student mappings.

	F linear	F quadratic
Design process	7.05*	16.13***
Interpersonal skills	5.74*	ns
Technical background	ns	ns
Genesis of the design	4.77*	ns
Marketing	ns	ns
Ethics	16.1***	33.39***

* = $p < .05$; ** = $p < .01$; *** = $p < .001$

3 Comparing experts and students

T-tests assuming unequal variance showed that at Time 1 expert maps had significantly more concepts and lines than did students (concept, $t[7]= 2.52$, $p < .05$; lines, $t[8]=3.34$, $p < .05$); however, experts and students did not differ in density or validity. There were no statistically significant expert-student differences on any of these dimensions at Time 2. Results for Time 3 showed that experts had significantly more lines and concepts (lines, $t[38]=2.60$, $p < .05$; concepts, $t[38]= 2.01$, $p < .05$), but did not differ from students in density or validity.

Table 4 summarizes the percentage of content coverage across the 6 categories for experts and for students, and summarizes t-tests and p values regarding student-expert comparisons. At the beginning of the design course, students and experts placed equal emphasis on two areas: interpersonal skills and technical background. Students differed from experts in four areas: the design process, motivation for the design, marketing and ethics. At the end of the first semester (Time 2), students closed the expert-novice gap in five of the six areas. The only difference pertained to marketing. At the end of their design experience (Time 3), students continued to differ from experts in two areas: marketing and ethics.

Table 4. Average percentage and t-tests comparing percentage of content coverage in expert and student and maps across the 6 identified categories.

	Design process	Interpersonal Skills	Technical Background	Motivation for design	Marketing	Ethics
Expert	.40	.29	.44	.42	.35	.46
Student						
Time 1						
M	.24	.16	.27	.16	.13	.10
T	2.30*	--	--	3.17*	2.21*	3.32**
Time 2						
M	.33	.36	.41	.38	.15	.60
T	--	--	--	--	2.09*	--
Time 3						
M	.30	.28	.40	.34	.11	.22
T	--	--	--	--	2.20^{+}	2.60*

-- = not significant, * = p < .05; ** = p < .01; $^{+}$ = approached significance (p < .06)

Because we were committed to using a research tool that also offered students a window into their own thinking, at the end of the course we asked students to identify and reflect on differences in their initial and final maps. Some student comments reflected initial skepticism about the value of the concept mapping task (e.g., "*I really didn't think that I would see big changes. But I can now understand").* Another student articulated the difference between his first and final maps in this way: *"The final concept map illustrates a more interactive, dynamic and complex relationship between the various concepts."* For this student, communication was the critical component in the design process (e.g., *"Although the ultimate goal is related to product or system, without effective communications the product or system could not be achieved"*).

In sum, quantitative analyses showed that students increased their knowledge of the design process; however, they did not appear to have greater knowledge integration (i.e., density did not change) or accuracy (i.e., validity did not change). Content analyses revealed similarities and differences between experts and students. These trends offer insight into the development of expertise in design. In the next section, we discuss the study's implications for psychological understanding of expertise and for educators' efforts to enhance students' conceptual and professional development.

4 Summary

This study used concept maps to identify key concepts in the biomedical engineering design process and explore expert-student differences. Despite considerable within-group variability, experts consistently demonstrated a more comprehensive and differentiated understanding of the design process than did students. For instance, in addition to focusing on the design process itself, experts attended to issues in the surrounding social context, including understanding the need for the design, overriding societal concerns such as ethics and regulatory requirements, interpersonal skills (e.g., teamwork, project management), and marketing. These findings offer an important avenue for understanding the nature of expertise. That is, they suggest that experts think of design not only in abstract theoretical terms, they also understand and consider the social context in which a design and designers function.

Essentially, our study shows that students moved from 'this to that.' We view students' initial maps as their assumptions about the design process. Their second maps reflect an abstracted knowledge grounded in course readings and lectures. Their final maps are the most expert-like. We believe these representations differ from initial maps because they reflect the voice of experience and an internalized knowledge of what it means to design something. What we want to know more about is the processes underlying these changes. Our current hypothesis is that the expert-novice gap is closed when students increase their domain knowledge *and* bring that knowledge to bear on an authentic problem in a realistic setting.

The development of our taxonomy yielded an ability to assess map contents. This is a significant development. We are testing the validity of our taxonomy by comparing results derived from analyses with its specific design concepts to rubrics used by other design educators. We expect this work to yield a 'thesaurus' of design terms. Establishing such a thesaurus should address issues of inter-rater reliability and the fact that our current judgments about what is an acceptable concept are fairly subjective. Another related concern is that our current assessment of proposition validity does not appear to discriminate novice and student conceptions. Thus we are seeking a way to express the more holistic nature of people's thinking about design (i.e., does it appear to be a linear or iterative process?), and are characterizing maps in terms of the extent to which they describe the design process (i.e., is it to the design level, prototype level?).

We are currently comparing the concept maps of students enrolled in this year's design class to measures of engagement and competence in design. For instance, students have responded to design scenarios across the year, allowing us to assess their developing abilities over time. We are also asking students to create a concept map of their senior design project and then relate that representation to other technologies that visually represent design problems. Finally, we are comparing what students say about the design process with what they actually do when designing something. Across the year we observed how three student design teams formed, and how they selected and attempted to solve a real medical problem. This work allows us to see how and whether students apply their conceptual knowledge and skills as they participate in organized, cumulative activities that may hold greater meaning for them.

In sum, our findings suggest that experts' knowledge cannot be reduced to a set of isolated facts because their knowledge is linked to contexts and conditions for its use. If this is the case, then design educators should place considerable emphasis on the conditions for applying the facts and procedures associated with the design process. In turn, assessment of student competence should focus not only on students' ability to recall facts, but on whether students know when, where, and how to use their knowledge.

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Pamplona, Spain 2004

KONTZEPTU MAPEN BIDEZ IKASKUNTZA ESANGURATSUA BULTZATZEN ETA BERE ADIERAZLEAK IKASLEENGAN ANTZEMATEN

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Laburpena: Lan honetan, mapa kontzeptualen erabilpenaren inguruko esperientzia aurkezten da eta zehazki, kontzeptu mapen analisiaren bidez ikaskuntza esanguratsuaren adierazleak ikasleengan antzematea izan da helburu nagusia, non San Fermin ikastolako DBHko 2. mailako ikasleek matematikako proportzionaltasunaren eta natur zientzietako energiaren gaia landu duten. Kontzeptu mapa ikasleen ikaskuntza esanguratsua bultzatzeko tresna ezin hobea dela aurreikusiz, tresna hau erabilia izan da gai hauei buruzko instrukzioak diseinatzerakoan, inplementatzerakoan eta baita ere, ikasleek lortzen duten ezagutza ebaluatzerakoan.

1 SARRERA: ERREFERENTZIA TEORIKOAK

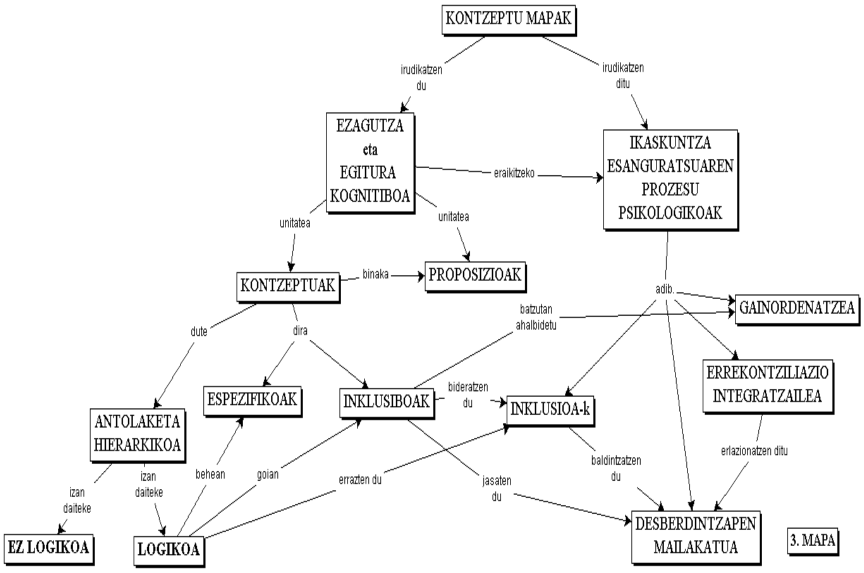
XX. mendearen azken aldera giza ikaskuntzari buruz ekarpen oso aipagarriak eta hezkuntza munduan eragin handia izan duten ekarpen teorikoak egon dira. Guztiak teoria konstruktibistetan barneratuz, adibide gisa aipatu ditzakegu Piaget (1971, 1973), Kelly (1963), Lev Vygotsky (1987, 1988), Johnson-Laird (1983) eta azkenik Ausubel (1968) eta Novak (1977, 1988). Proposamen hauetan giza ikaskuntzaren prozesua azaldu nahi duten kontzeptu ezberdinak aurkitzen ditugu, hala nola, Piaget-en asimilazioa, akomodazioa, moldaera eta orekatzea, Kelly-ren ezagutza moldeak eta eraikin unitateak, Lev Vigotsky-ren gizabanakoaren interakzio soziala eta ikurren barneratzea, Johnson-Laird-en buru-ereduak eta ezagutza blokeak eta, baita ere, Ausubelen eta Novakek sakontzen eta berritzen duen ikaskuntza esanguratsua. Guztiak izan dute bere eragin positiboa hezkuntzaren munduan, non ikasleen ikaste prozesuaren aurrean irakasleok ezagutza eta tresneri aipagarriak jaso ditugun, baina J. A. Moreiraren ustez (1997) Ausubelek proposatzen duen ikaskuntza esanguratsuaren kontzeptua eta Novakek ondoren aberasten duena da eskolan gauzatzen diren ikaste prozesuak hobetzeko daukagun egokiena, eta hori horrela dela dio Ausubelen teoria, aurkeztu diren besteak ez bezala, gelan gertatzen den ikaskuntza prozesuari buruzko teoria bat delako.

Ausubelek egiten duen ekarpen garrantzitsuenetako bat da giza ikaskuntza bi mutur dituen jarraitasun bat bezala ulertzea, non mutur batean egongo litzatekeen pertsonak dakiena eta jaso behar duen informazio berriaren arteko harreman arbitrarioak eta ez substantzialak, eta bestean harreman ez arbitrarioak eta substantzialak, horrela bereizten dituelarik ikaskuntza memoristikoa eta esanguratsua. Ausubel eta Novak-en ikaskuntza esanguratsua kontzeptua sakonago aztertuz lehenik eta behin esan daiteke ikaskuntza esanguratsua prozesu psikologiko eran azaltzen dela, non kontzeptuek beraien arteko erlazio hierarkikoetatik jasotzen duten esanahia eta beraien artean gertatzen diren inklusioen, desberdintzapen mailakatuen, gainordenatzeen eta errekontziliazio integratzaileen prozesuen bidez egiten dela ikasten duen pertsonaren egitura kognitiboa eta ezagutza aberastu eta zabaldu.

Kontzeptu mapen tresna Novaken ekarpen zuzena denez, esan behar da eskolako testuinguruan eta ikaskuntza esanguratsua bultzatzerakoan tresna hau ikaste-irakaste prozesuaren momentu eta eginkizun desberdinetan erabiltzeak oso emaitza positiboak eskaini dituela. Gaur egun ja badira ikerketa lan aipagarriak (Brody 1993; González 1993, 1994, 1995, 1997a, 1997b, 2001; Guruceaga y González 2004) zeintzuk baieztatzen duten kontzeptu mapak oso lagungarriak direla ikasleak bere ikastearen aurrean ikasleen jarrera positiboagoak eta aktiboagoak errazterakoan, eskolako instrukzioak kontzeptualki gardenagoak izaterakoan eta ezagutza zientifikoa ikasleen ezagutza psikologikoan eraldatzerakoan. Ikaskuntza esanguratsuago bat bultzatzearen adibideak dira, hain zuzen ere lan honetan aurkeztuko dena.

2 KONTZEPTU MAPEN ERABILGARRITASUNA

Kontzeptu mapak pertsonen ezagutza islatzen duen tresna bat da, eta ondorioz bai ezagutza esanguratsuaren eta baita ere ikaskuntza memoristikoaren ezaugarriak islatu ditzake, ikaskuntza mutur hauek identifikatzeko aukera ezin hobea eskainiko dutelarik. Kontzeptu mapa batean adieraziko da egileak zein kontzeptu erabiltzen dituen gai baten inguruan, zeini eskaintzen dion aipagarritasun hierarkiko handiena, zeintzuk diren informazio berriarekin erlazionatzeko erabiliko dituen kontzeptu zubiak edo inklusoreak, hauetatik zeintzu diren mailaka desberdintzen dituenak eta azkenik zeintzu diren proposatzen dituen errekontziliazio integratzaileak (ikus 1.irudia).



1.irudia

3 KONTZEPTU MAPAK ERABILI DIREN LAN PRAKTIKOEN TESTUINGURUA

Lan honetan aurkezten duguna Iruñerriko San Fermin Ikastolan DBHko bigarren mailako ikasleekin burututakoa da eta bi gai desberdinen inguruan gauzatu da, energiaren gaia Natur Zientziak arlotik eta proportzionaltasunaren gaia Matematikak arlotik. Bai energiari buruzko instrukzio modulua, baita proportzionaltasunari buruzko instrukzioa ere 2002-2003 ikasturtean zehar jarri ziren praktikan, DBHko bigarren mailari zegokion lau geletatik bitan. Zehazki A eta B taldeak izan ziren parte hartu zutenak, osotara 63 ikaslek, eta hauetariko 32ri dagozkien kontzeptu mapak aztertu dira, inplementazio aurretik eta ondoren bakoitzak egindako mapak hain zuzen ere.

4 ENERGIAREN ETA PROPORTZIONALTASUNAREN KONTZEPTUAK IRAKASTE ETA IKASTERAKOAN KONTZEPTU MAPEN ERABILERA

4.1 ENERGIARI BURUZ MODULUA DISEINATZERAKOAN ERREFERENTZIAKO KONTZEPTU MAPA ERAIKITZEN

Gure aldetik eta eztabaida askoren emaitza gisa DBH2ko ikasleekin energia kontzeptua lantzeko honako erabakiak hartu genituen (Jesuína, P. y Kátia, H., 2004; Hierrezuelo y Montero, 1988):

- Erreferentziako kontzeptu mapan hiru inklusore erabili energia kontzeptuari esanahia ematerakoan: energia baliabide gisa ulertzea, energia aldaketekin erlazionatzea eta gorputzen propietate gisa ulertzea.
-
- Ondoren inklusore bakoitzaren garapena lantzea, beti ere aurretik erabakiak genituen kontzeptuak erabiliaz. Gorputzen propietatean subsumitua energia forma kontzeptua erabiltzea onartzen da, naiz eta jakin halako kontzeptuak energiaren izaera materiala duenaren kutsua izan. Aldaketetan subsumituak planteatzen ditugu transformazioak, kontserbazioa eta transferentzia. Azkenik, iturri energetikoa hartu zelarik baliabide kontzeptuari esanahia emateko inklusore aipagarriena bezala.
-
- DBHko mailan kokatu behar zen interbentzioa zenez baloratu zen kontzeptu mapan lana kontzeptua ez sartzea.

- Azkenik, erreferentziako kontzeptu mapa 47 kontzeptuekin antolatzen da. DBH2ko ikasleekin kontzeptu guztiak erabiltzea gehiegizkoa dela ikusten da eta ondorioz lehenengo kontzeptu maparako 37 aukeratzen dira eta bigarren kontzeptu maparako 41. Hiruen arteko desberdintasuna kontzeptu espezifikoetan egongo da.

Erreferentziako kontzeptu mapa eraiki ondoren, eta Novakek "Project LEAP" delakoan proposatzen duena jarraituz instrukzioaren antolaketari ekiten diogu. Instrukzioa hiru faseetan diseinatzen da: sarrera, lantze edo fokuratze fasea eta laburpen fasea. Lehenengoan instrukzioan landu nahi den kontzeptu eta proposizio nagusiak aurkezten dira, hauek beti ere maparen maila hierarkikoenean azaltzen direlarik eta inklusore nagusiei eta beraien esanahi orokorrenei lotzen zaielarik. Bigarren fasean kontzeptu inklusiboenarekiko adierazgarriak diren beste kontzeptu inklusoreen mailakaturiko desberdintzapenak eta errekontziliazioak identifikatu eta garatuko dira. Azkenean, energiaren inguruan lantze faseetan jasotako informazioa biltzea, erlazionatzea eta aplikatzea bultzatuko duen azken jarduera sorta gauzatzen da (ikus 1.taula).

INSTRUKZIO MODULUA. 1 TAULA

	INSTRUKZIOAREN AURRETIKO KONTZEPTU MAPA
	SARRERA
A1	ENRGIARI BURUZ AURRETIKO IRAKURGAIA
A2	ENERGIAZ ZER PENTSATZEN DUGU?
A3	KONTZEPTU MAPA

	LANTZE FASEA- FOKURATZE FASEA
	LANTZE edo FOKURATZE I
A4-A5	ENERGIA ETA GORPUTZEN ALDAKETAK
A6	ENERGIA TRANSFERITU EGITEN DA
A7	KONTZEPTU MAPA
	LANTZE edo FOKURATZE II. ENERGIA FORMAK ETA TRANSFERENTZIAK
A8- A9-A10	ENERGIA FORMA DESBERDINETAN AGERTZEN DA
A 11	KONTZEPTU MAPA
A 12	BEROA, ENERGIA TRANSFERITZEN DEN ERA ARRUNTENA
A 13	INDARRA. ENERGIA TRANSFERITZEKO BESTE ERA BAT.
A 14	KONTZEPTU MAPA
	LANTZE edo FOKURATZE III. BIHURGAILUAK
A 15	BIHURGAILUAK: ENERGIAREN TRANSFORMAZIOETAN TREBEAK DIREN SISTEMAK. IZAKI BIZIDUNAK (1)
A 16	ENERGIAREN TRANSFORMAZIOETAN TREBEAK DIREN SISTEMAK(2). MAKINAK.
A17	LABORATEGIAN PILA BAT ASMATZEN
A18	BIHURGAILUEK ENERGIAREN TRANSFORMAZIO BAKARRA EZ DUTE EGITEN
	LANTZE edo FOKURATZE IV
A 19	ENERGIAREN LEGEAK
A 20	ENERGIARI BURUZ ARIKETAK
A 21	KONTZEPTU MAPA
	LANTZE edo FOKURATZE V. BALIABIDE ENERGETIKOAK
A 22	GURE GIZARTEARENTZAT EZINBESTEKOA DA BALIABIDE ENERGETIKOAK IZATEA
A 23	ERABILTZEN DITUGUN ENERGIAK
A 24	ENERGI ITURRIAK
A25	ENERGIA ITURRIEI BURUZ ARIKETAK eta SINTESI TAULA
A 26	ENERGIA ELEKTRIKOA: GUK ZUZENEAN GEHIEN KONTSUMITZEN DUGUN ENERGIA

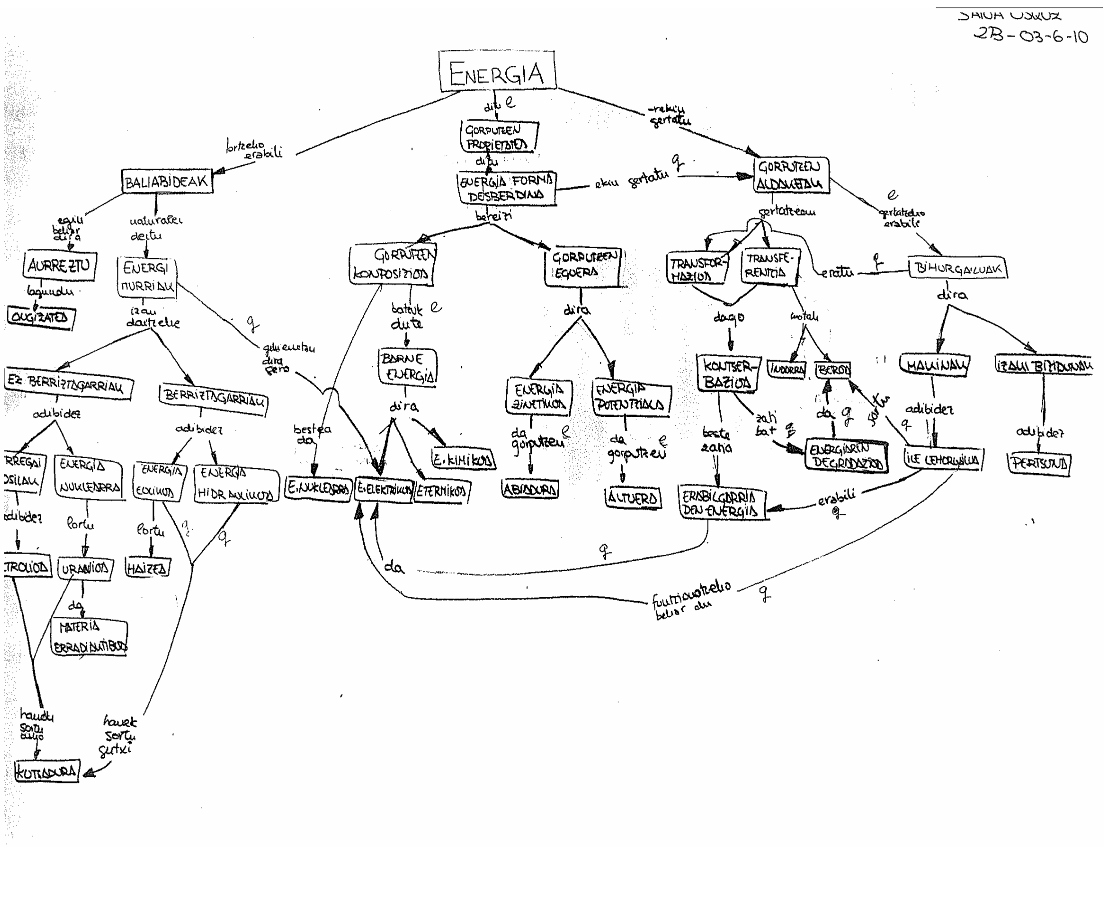
	LABURPEN FASEA
A 27	ENERGIAREN EKOIZPENA ETA KONTSUMOA BALORATZEN
A 28	HAUSNARKETAK ETA PROPOSAMENAK
	INSTRUKZIOA ONDORENGO KONTZEPTU MAPA

4.2 ENERGIAREN INSTRUKZIO MODULUAREN AURRETIK ETA ONDOREN IKASLEEK ERAIKI DITUZTEN KONTZEPTU MAPAK AZTERTZEN

Atal honetan bi ikasleen kontzeptu mapak aztertuko ditugu, konkretuki 28. eta 16. ikasleenak. Ohizko ebaluaketetan bi ikasleak onak agertzen dira, hala eta guztiz ere kontzeptu mapen laguntzaz ikusiko dugu 28. ikasleak ikaste prozesu esanguratsuagoa lortu duela 16.a baino.

28. ikaslearen, hau da Saioaren bi mapak aztertuko ditugu jarraian. Ikasle honek lehenengo mapatik agertzen du kontzeptu mapan kontzeptuak eta lotura hitzak ongi bereizteko joera. Eta azken hauen kalitateari begira esan beharko genuke bigarren mapak lortzen duen konplexutasunarekin loturiko proposizio konplexuagoak egiten dituela, baina era berean, batzutan akatsak eratuz, adibidez, gorputzak kontzeptua loturetan sartzen duenean bezala.

Bat bateko begi-bistakoa eginaz lehenik eta behin ikus daiteke Saioak instrukzioaren aurretik ez dituela kontzeptu inklusiboak bereizten eta era berean ez dituela kontzeptuak hierarkizatzen, ondorioz hasierako kontzeptu maparen esanahia sinpleegia izango delarik. Lehenengo maparen ezaugarria guztiz bat dator ikasleak kontzeptuen artean errekontziliaziorik ez eratzearekin. Instrukzioaren ondoren, berriz, Saioak ederki identifikatzen ditu hiru inklusore nagusiak, hala nola, baliabideak, gorputzen propietatea eta aldaketak. Era berean ikus daiteke inklusore hauen desberdintzapen mailakatu oso aipagarriak agertzen dituztela, gainera subsumitzen dituztelarik beste kontzeptu guztiak. Kontutan hartuz lehenengo mapan 24 kontzeptu besterik ez zituela erabiltzen oso nabarmena da ikasle honek izan duen kontzeptu subsunzioaren kalitatea. Era berean oso ikusgarria da Saioak desberdintzapen mailakatu bakoitzaren barnean eta ezberdinen artean eratu dituen errekontziliazioetaz ohartzea. Azken finean instrukzioaren ondoren neska honek erakusten duen energiari buruzko ezagutza era esanguratsuan asko aberastu delarik. Merezi du azterketa berezia egitea ikasleak bi mapetan egiten dituen akatsen inguruan. Lehenengo mapan kontzeptuen esanahi zientifikoarekin arazoak nabarmentzen dira Saioak adierazten duenean, energia iturrietaz hitz egin beharrean energia bera izan daitekeela berriztagarria eta ez-berriztagarria, edo energia zinetikoa hartzea energia iturri gisa, edo energia eta indarra identifikatzean, edo makinak energia daukatela esatean. Bigarren mapan berriz saioak argitu egiten ditu aurreko nahasketa batzuk, baina landu berriak diren beste kontzeptuekin arazoak adierazten ditu, adibidez, dionean bihurgailuak erabiltzen direla gorputzen aldaketak gertatzeko. Saioaren kasuan esan daiteke bigarren mapak ikaslearen ikaste prozesu oso esanguratsua islatzen duela eta, era berean, energia kontzeptuaren arazo aipagarrienak transformazioa eta bihurgailua kontzeptuen arteko harremanetan azaleratu direla.



16. ikaslearen, hau da Ikerren bi mapak aztertuko ditugu jarraian. Ikasle honek lehenengo mapatik agertzen du kontzeptu mapan kontzeptuak eta lotura hitzak ongi bereizteko joera. Oraingoan ere esan daiteke bigarren mapak eskaintzen dituela proposizio konplexuagoak, eta honek ere batzutan akatsak eratuz, adibidez, energia kontzeptua lotura batean agertuz.

Oraingoan ere bat bateko begi-bistakoa eginaz lehenik eta behin ikus daiteke Ikerrek instrukzioaren aurretik ez dituela kontzeptu inklusiboak bereizten eta era berean ez dituela kontzeptuak hierarkizatzen, era nabarmenean ikusten delarik ikasleak ikaskuntza memoristikoaren isla garbia den kontzeptuen arteko kate lineal luze bat. Instrukzioaren ondoren Ikerrek kontzeptu asko barneratzen ditu (lehenengo mapan %62 erabiltzen bazituen, bigarren mapan %90 erabiltzen ditu) eta kontzeptu inklusoreak identifikatze nahia adierazten du, baina ez ditu ongi identifikatzen, azken finean guztiz ezkutuan gelditu delarik aldaketen kontzeptua. Ondorioz, ikus daiteke Ikerrek ez dituela kontzeptuak era logikoan hierarkizatzen, eta desberdintzapen mailakatu aipagarririk ez dituela eskaintzen. Bigarren kontzeptu mapa honetan nahasketa handiago eta akats kopuru aipagarriagoak agertzen direlarik. Adibidez, energia berriztagarriak eta ez-berriztagarriak bigarren mapan agertzen duten desberdintzapean ikus daiteke Ikerrek ez dituela bereiztu energia formak eta iturriak, ondoren arazo honi irtenbidea bilatuz errekontziliazioen bidez. Oso aipagarria da, baita ere, ikustea non kokatu dituen Ikerrek transformazioa eta transferentzia kontzeptuak. Badirudi nolanahi zintzilikatu dituela energia forma ezberdinetatik, horrelako antolaketa kontzeptuen arteko harreman guztiz nahasiak adierazten dutelarik. Nahasketa honen adierazle dira Ikerrek azaleratzen dituen proposizio akastunak. Egia da instrukzioaren ondoren Ikerrek proportzioan askoz ere akats gutxiago egin dituela (lehenengo mapan 25 proposizioetatik 7 akastun egin ditu, eta bigarren mapan berriz 49 proposizioetatik 7). Akatsak, esan bezala energia iturriak eta formak nahastearekin zerikusia dute. Ikerrek egindako kontzeptu mapen azterketak esaten digu ez duela Saioak lortu duen ezagutza bezain logikoa lortu, eta ondorioz bere ikaste prozesua ez dela izan hain esanguratsua.

Azalpen honekin adierazi nahi izan dugu kontzeptu mapak erabiliaz ezagutu dezakegula ikasle jakinek lortzen duten ezagutza nolakoa den eta, baita ere, zer nolako ikaste prozesua garatu duten. Baina, noski, horrelako azterketa bat ikasgela batetako ikasle kopuru adierazgarri batekin egiten bada adieraziko liguke planteatutako instrukzioak zer nolako onurak eta hutsuneak azaleratzen dituen, eta ondorioz zer nolako berrikuntzak eta aldaketak proposatu beharko liratekeen. Adibidez, aipatzen ari garen ikerketa honetan 32 ikasleen instrukzioaren aurretiko eta ondorengo kontzeptu mapen azterketa burutu izan dela esan dezakegu, orokorrean energia kontzeptuaren ikaste eta irakaste prozesuaren inguruan aipagarriak diren ondorioak atera direla. Adibidez, lehenik eta behin esan behar dugu ikasleen ikaskuntza esanguratsuagoaren isla garbiak azaldu zaizkigula. Hala nola, kontzeptuen erabilpena era aipagarrian areagotzea, proposizio akastunak nabarmenki gutxitzea, kontzeptuen antolaketa hierarkikoa kontzeptuen izaera inklusibo eta logikoarekin bateratuagoa azaltzea; “energia forma desberdinak”, “transformazioa”, “transferentzia”, “bihurgailuak”, “energia iturriak”, bezalako kontzeptu inklusiboen desberdintzapen mailakatuagoa areagotzea eta azken hauek errekontziliatuagoak azaltzea.

4.3 PROPORTZIONALTASUNARI BURUZ MODULUA DISEINATZERAKOAN ERREFERENTZIAKO KONTZEPTU MAPA ERAIKITZEN

Kantitateak, batzuk besteekin erlazionatuta kontutan hartzeko beharra, ikasle askorentzat arazo bilakatzen da eta oztopo bihurtzen da ikasi behar diren eta proportzionaltasunaren ideiarekin erlazioa gordetzen duten edukiak ulertzeko. Kontzeptu honen ulermena eta ondorioz, proportzionaltasun problemen ebazpenaren arrakasta barne faktoreei, ikaslearen garapen kognitiboa adibidez, eta kanpo faktoreei lotuta dago, arrazoia eratzen duten zenbakiak eta konparatzen diren magnitudeak adibidez.

Hau guztia kontutan haztuz, DBH2ko ikasleekin proportzionaltasun kontzeptua lantzeko hurrengo erabakiak hartu genituen (Fiol, M.L. y Fortuny, J.M., 1990):

- Erreferentziako kontzeptu mapan magnitude kontzeptutik abiatuta, bi inklusore erabili proportzionaltasuna kontzeptuari esanahia ematerakoan: proportzioa eta erlazio proportzionala. Proportziora magnitude berberaren bi kantitatek eratzen duten arrazoitik iristen gara eta erlazio proportzionalera berriz, bi magnitude desberdinen artean egon daitekeen harremanaren posibilitatetik.
- Ondoren inklusore bakoitzaren garapena lantzea, alde batetik arrazoia kontzeptua egoera matematiko desberdinetan aztertuz eta bestetik, bi magnitudeen arteko harreman proportzionala adierazteko existitzen diren lau formak erabiliaz.
- Erreferentziako kontzeptu mapa, 25 kontzepturekin antolatzen da.

Jarraian, kontzeptu mapa horretan identifikatuak izan dira instrukzio jarduerei zentzua emango dioten eremu kontzeptualak. Instrukzio hauen jarduerak Novak-ek gidatu zuen "Project LEAP" delakoan oinarritu dira eta horren arabera, hiru fase desberdinetan antolatuak izan dira: sarrera, fokuratze fasea eta laburpen fasea.

4.4 PROPORTZIONALTASUNAREN INSTRUKZIO MODULUAREN AURRETIK ETA ONDOREN IKASLEEK ERAIKI DITUZTEN KONTZEPTU MAPAK AZTERTZEN

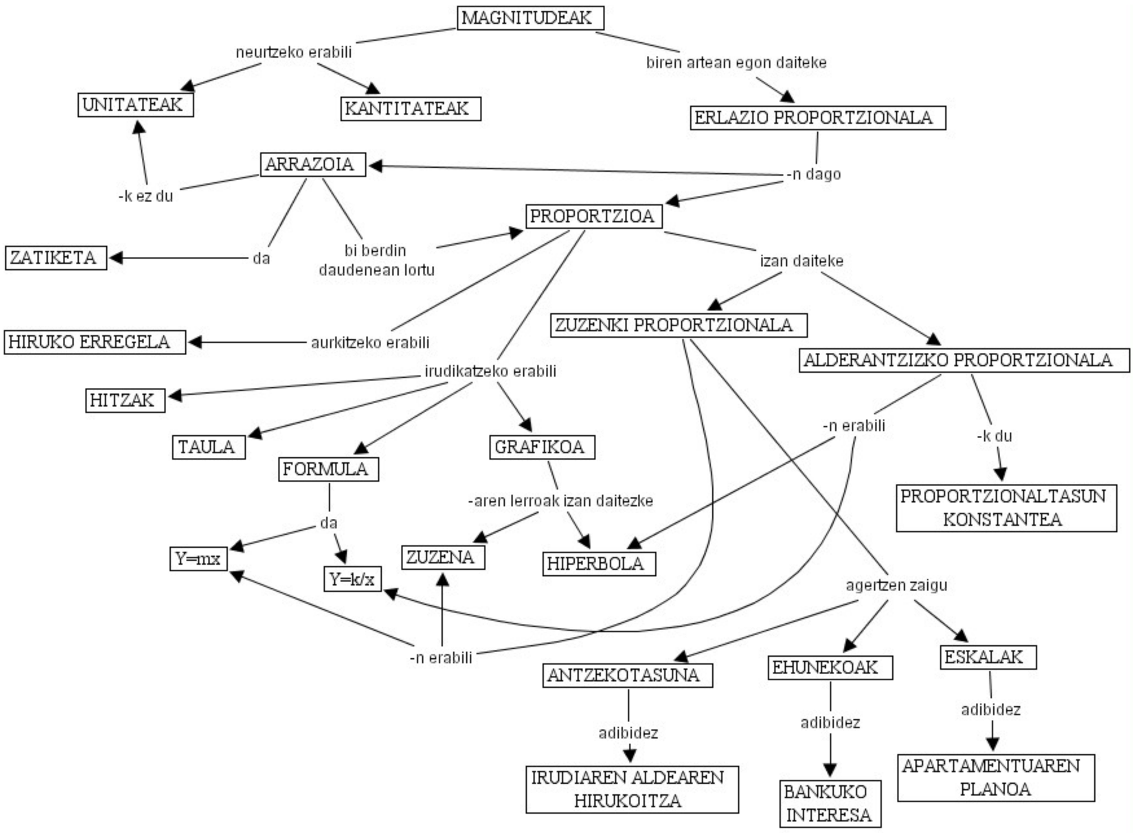
Atal honetan bi ikasleen kontzeptu mapak aztertuko ditugu, konkretuki 28. eta 16. ikasleenak. Ohizko ebaluaketetan bi ikasleak onak agertzen dira, hala eta guztiz ere kontzeptu mapen laguntzaz ikusiko dugu bi ikasle hauen ikaste prozesu esanguratsua, modu desberdinetan antolatzen dela bakoitzaren egitura kognitiboan .

16. ikaslearekin hasiko gara, Ikerrek egin dituen kontzeptu mapak aztertzen. Ikasle honek lehenengo mapatik agertzen du kontzeptu mapan kontzeptuak eta lotura hitzak ongi bereizteko joera. Esan daiteke bigarren mapak eskaintzen dituela proposizio konplexuagoak.

Ikasle honek 14 kontzeptu erabili ditu bere hasierako mapan eta bukaerakoan berriz, zerrendako 25 kontzeptuak erabili ditu. Hasierako mapan ikusten da ez dituela bi kontzeptu inklusiboak bereizten eta era berean, ez dituela kontzeptuak hierarkizatzen, era nabarmenean ikusten delarik ikaskuntza memoristikoaren isla garbia den kontzeptuen arteko kate lineal luze bat. Instrukzioaren ondoren Ikerrek kontzeptu asko barneratzen ditu eta ikus daiteke zein modutan barneratu duen arrazoia kontzeptua, osotasuneko esanahia eman diolarik zuzenki bai proportzioa kontzeptuarekin eta baita ere, erlazio proportzionala kontzeptuarekin erlazionatu duelarik. Erlazio proportzionalak dagokion maila hierarkikoa hartzen du, baina ez da zuzenean erlazionatzen zuzenki proportzionala ala alderantzizko proportzionala kontzeptuekin. Harreman hori proportzioa kontzeptuaren bidez egiten du Ikerrek eta era berean, ikus daiteke inklusore horren desberdintzapen mailakatu oso aipagarriak agertzen direla, beste kontzeptu guztiak subsumitzen dituelarik eta hori irudikatzeko agertzen dizkigu, egoki definituak azpiko maila hierarkiko batetan modulo instrukzionalaren zehar landu diren lau adierazpideak, hau da, hitzak, taula, formula eta grafikoa. Espresio mota desberdinen eta erlazio proportzional bi formen artean dauden zeharkako erlazioak ere ongi islatuak agertzen dira eta era berean, proportzionaltasun zuzeneko adibide gisa moduloan aztertu diren hiru egoerak azken maila hierarkiko batetan ongi kokatuak agertzen dira. Behar bada, zentzu gutxien duen proposizioa alderantzizko proportzionala eta proportzionaltasun konstantearen artean definitzen duena da, akatsa izan gabe modu egokienean ez baita kokatu azken kontzeptu hori. Beraz, esan dezakegu Ikerren kasuan bigarren mapak ikaslearen ikaste prozesu oso esanguratsua islatzen duela.

Oraingoan berriz, 28. ikaslearen, hau da Saioaren bi mapak aztertuko ditugu . Ikasle honek lehenengo mapatik agertzen du kontzeptu mapan kontzeptuak eta lotura hitzak ongi bereizteko joera. Eta azken hauen kalitateari begira esan beharko genuke bigarren mapan lortzen duela kasu guztietan proposizioak esanahi egokia edukitzea, bereziki lehenengoan hainbat kasutan erabiltzen duen geziaren zentzuagatik.

Bat bateko begi-bistakoa eginaz lehenik eta behin ikus daiteke Saioak instrukzioaren aurretik ez dituela kontzeptu inklusiboak bereizten, kontzeptu mapa unitateak kontzeptua erabiliz hasten da eta era berean ez dituela kontzeptuak hierarkizatzen, ondorioz hasierako kontzeptu mapan proposizio akasdun asko dago. Gainera lehenengo mapan kontzeptu kopuru txikia erabiltzen du, 11 hain zuzen ere.Instrukzioaren ondoren, berriz, Saioak ederki identifikatzen ditu bi inklusore nagusiak, hala nola, proportzioa eta erlazio proportzionala eta zerrendako 25 kontzeptuak kokatzen ditu. Instrukzioaren ondoren Ikerrek egin duen bezalaxe, kontzeptu asko barneratzen ditu eta ikus daiteke zein modutan barneratu duen arrazoia kontzeptua, osotasuneko esanahia eman diolarik zuzenean proportzioa kontzeptuarekin erlazionatuz. Ikerren antzera, erlazio proportzionalak dagokion maila hierarkikoa hartzen du, baina ez da zuzenean erlazionatzen zuzenki proportzionala ala alderantzizko proportzionala kontzeptuekin. Harreman hori proportzioa kontzeptuaren bidez egiten du Saioak ere, ondoren ez ditu kontzeptuak era hain logikoan hierarkizatzen, eta desberdintzapen mailakatu aipagarririk ez ditu eskaintzen. Bigarren kontzeptu mapa honetan nahasketa handiagoa dago, bereziki erlazio proportzionalaren lau adierazpideak espresatzeko, baina espresio mota desberdinen eta erlazio proportzional bi formen artean dauden zeharkako erlazioak ongi islatuak agertzen dira. Aipagarria da hiruko erregela kontzeptuak hartzen duen kokapena, proportzionaltasun zuzeneko adibide gisa moduloan aztertu diren hiru egoerak azken maila hierarkiko batetan agertu beharrean, horiei lotzen zaie hiruko erregela azken maila hierarkikoan. Kasu honetan ere, proportzionaltasun konstantea kontzeptua nahiko zintzilikatua geratzen da, oraingoan zuzenki proportzionala kontzeptuari lotuta. Gure ustez, Saioak ez du Ikerrek lortu duen ezagutza bezain logikoa lortu, eta ondorioz esan dezakegu bere ikaste prozesua ez dela izan hain esanguratsua.



IKER-en BUKAERAKO MAPA

Gorago energia kontzeptuaren kasuan eman den azalpenak, berdin balioko liguke kasu honetan ere, eta orokorrean proportzionaltasun kontzeptuaren ikaste eta irakaste prozesuaren inguruan aipagarriak diren ondorioak atera direla esateko moduan gaude. Adibidez, lehenik eta behin esan behar dugu ikasleen ikaskuntza esanguratsuagoaren isla garbiak azaldu zaizkigula. Hala nola, kontzeptuen erabilpena era aipagarrian areagotzea, proposizio akastunak nabarmenki gutxitzea, kontzeptuen antolaketa hierarkikoa kontzeptuen izaera inklusibo eta logikoarekin bateratuagoa azaltzea; bi proportzionaltasun motak eta lau adierazpideak ongi bereizteko kontzeptu inklusiboen desberdintzapen mailakatuagoa areagotzea eta azken hauek errekontziliatuagoak azaltzea.

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