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Proceedings of the Third Conference on Concept Mapping

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Proceedings of the 3rd International Conference on Concept Mapping

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Preface

Welcome to CMC 2008, the Third International Conference on Concept Mapping, and to Tallinn and Helsinki.

This conference reflects the maturity of the concept mapping community from around the world, which for the third time gets together to share research and experiences. We are confident the community will continue to consolidate and work together, and hope that we take advantage of this meeting to get stronger as a group, taking concept mapping to users all around the world and to all domains of knowledge.

This year we have a strong program that covers a variety of topics and we welcome participants from countries that had not participated in previous conferences.

The Program Committee had a tough time selecting the papers that would be presented orally and as posters from a large number of high quality submissions. We thank the members of the Committee for their effort and hard work. And of course, the conference would not take place if it were not for all the authors that are willing to share their work with the concept mapping community.

The high quality of papers is complemented by outstanding invited speakers: Joseph D. Novak, Ian Kinchin and Otto Silesky. Panels that we expect will generate a lot of discussion among the participants complete the Program.

Organizing a Conference that moves between two countries and across the Gulf of Finland takes an outstanding Local Organization Committee and we were fortunate to count with such a group. The Universities of Tallinn and Helsinki have also gone out of their way to make sure the Conference is a success. Finally, we thank the sponsors whose support was crucial in making the Conference a reality.

Alberto J. Cañas, Priit Reiska, Mauri Åhlberg
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A CASE STUDY IN ORGANIZING AND PRESENTING A COURSE WITH CONCEPT MAPS AND KNOWLEDGE MODELS

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Abstract. This work contains a description of a case study in the creation and delivery of a course entitled Web-Enabled Applications that utilized concept mapping and knowledge modeling as the framework for material organization and presentation. While the knowledge modeling approach described here has been in existence for some time, few empirical studies in its use for course development and delivery are to be found. The current work reports methods and statistics pertaining to the development of the knowledge model, how it evolved during use in the course, and student attitudes toward this mode of course presentation.

1 Introduction

Work at the Institute for Human and Machine Cognition has given rise to the notion of a knowledge model (Ford et al. 1991; Ford, Cañas & Coffey 1993) as a linked aggregation of concept maps (Novak & Gowin, 1984) and other electronic resources that elucidate the concepts in the maps. Although the idea of knowledge modeling has been with us for some time, their use in course delivery has not been extensively studied or documented. Some interesting barriers have existed to the assessment of such use. Several of the larger knowledge models created at IHMC have undergone relatively little evaluation because of educational material format. For instance, use of knowledge models in military training is somewhat problematic because of the long tradition of very structured, lockstep training regimens and tightly proscribed types and organization of instructional materials. Similar difficulties were encountered in the nuclear power industry where training materials and protocols are strikingly similar to those utilized by the military.

This paper reports results of work on the development and use of a knowledge model as the framework for the organization of materials and the presentation of a university-level course. The CmapTools (Cañas et al. 2004) software was used to build a knowledge model for a course entitled "Web-Enabled Applications" that pertains to various technologies such as XML, XHTML, XSLT, Javascript, AJAX, and PHP. The knowledge model was then used as the learning environment through which the course was delivered and as the organizing factor for all resources associated with the course. No standard course delivery software (such as PowerPoint™) was used in the course.

After a brief review of the literature pertaining to course delivery with concept maps and knowledge models, the remainder of this article will briefly describe the creation of a knowledge model of the course content and then elaborate a case study in the use of the materials to deliver the course. The case study includes some statistics pertaining to the size of the knowledge model, details of how the knowledge model was used and modified during the semester, and results of surveys pertaining to student attitudes to this mode of presentation. The next section contains a review of literature that is relevant to the current work.

2 Relevant Literature

Advance Organizers are devices that are used to present global summarizations of content to be learned by the student. Ausubel et al. (1968, 1978) state that advance organizers improve the ability of students to incorporate new knowledge into existing knowledge, a key factor in meaningful learning and the retention of knowledge. Several studies have been described that utilized "expert maps" as advance organizers for students in a variety of knowledge domains. Novak (1998) suggested that, if created at a level of generality that is appropriate relative to the learner's current understandings, concept maps can serve as powerful advance organizers. In their new model of education based upon concept mapping and CmapTools, Novak & Cañas (2004) describe the use of expert skeleton maps. Others have described the use of expert maps as advance organizers in the teaching of undergraduate science courses (Heinze-Fry, 2004), in preservice teacher training in pedagogy and subject area content (Colli et al. 2004), in secondary school Physics teaching (Alias, 2006), and in mathematics teacher training (Caldwell et al. 2006).

With regard to the use of full-fledged knowledge models as educational vehicles, results are more difficult to find. Some studies have described the use of knowledge models in informal education. Briggs et al. (2004)

from the Center for Mars Exploration at NASA Ames described the use of this approach to knowledge modeling to organize a large number of electronic resources. Arbea et al. (2004) described the Comenius Project, which utilized the concept of a knowledge model to organize materials pertinent to traditional Spanish festivities.

A few studies of the use of Knowledge models as organizing factors in more formal educational settings have been described as well. Fernandez et al. (2004) described a knowledge model that was used to teach movie (film) analysis and production. Coffey (2005) described the use of a knowledge model in a computer science course on data structures, and Basso & Margarita (2004) described the use of a knowledge model that actually integrated with the Plone open source Content Management System, which was also the topic being taught. The results presented in these studies were all preliminary. The next sections elaborate the idea of a knowledge model in the context of the one used in this study, followed by a description of the current work.

3 Knowledge Modeling

This section contains a description of a knowledge model (Ford et al. 1991; Ford, Cañas & Coffey 1993) as the term is used at the Institute for Human and Machine Cognition. This section describes the structuring of a Knowledge Model to present a visual representation of the structure of course content to students. *CmapTools* (Cañas et al. 2004) was used to create and deploy the knowledge model that is the topic of this article. The section concludes with a description of resources that are typical of those that were used in the current work.

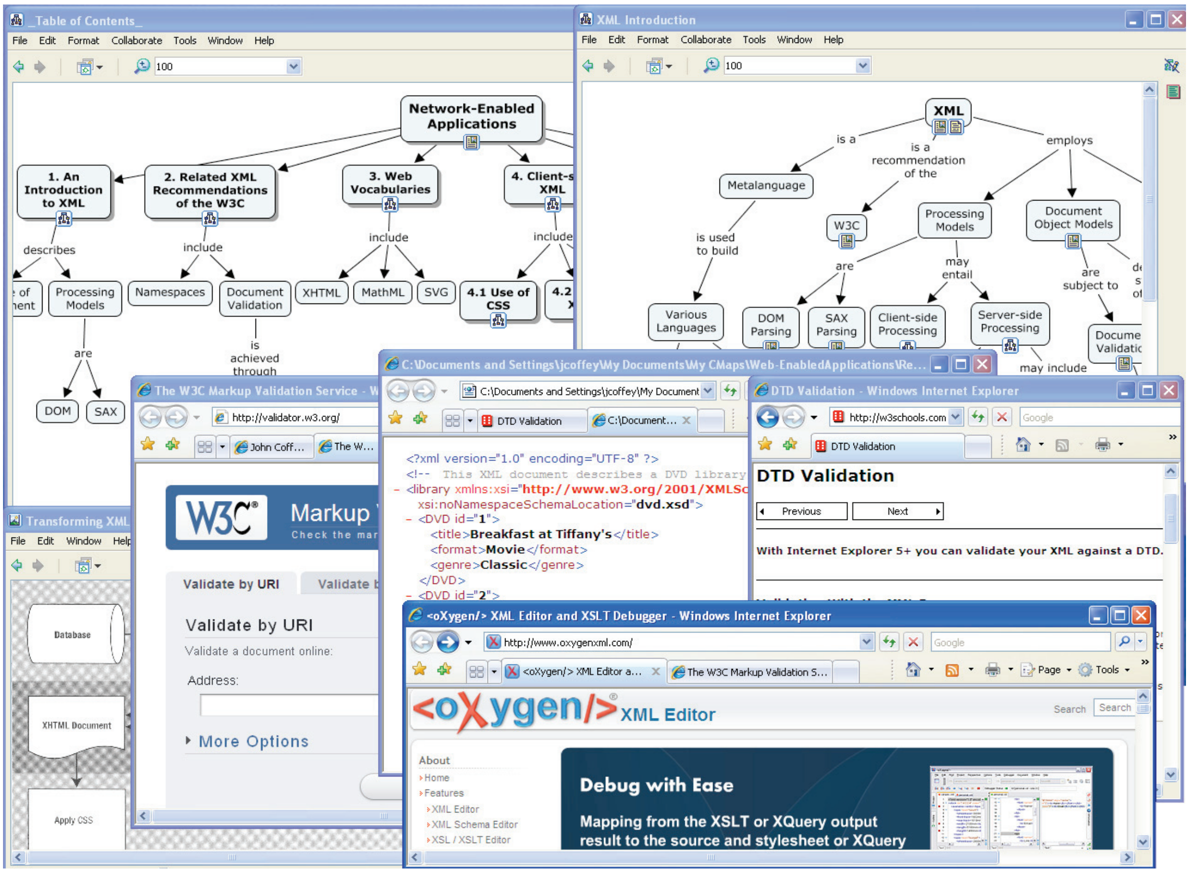

Figure 1. Representative components in a Knowledge model used in the course on Web-Enabled Applications.

Knowledge Models are hypermedia representations structured by Concept Maps, with a general, top-level map as the starting point and more detailed maps pertaining to the central concepts in the Top Level Map (Ford Cañas & Coffey 1993). Documents in any electronic medium might be associated with the concepts in the Concept Maps. *CmapTools* provide support for the creation and representation of knowledge models pertaining to a knowledge domain. Knowledge models created with *CmapTools* may be developed and accessed over a network. Such knowledge models can serve as pedagogical adjuncts to courses or as the main organizing and presentation factor, as was the case in the current work.

Figure 1 contains a graphic of representative components of the Knowledge Model pertaining to the Web-Enabled Applications course. The scenario depicted in Figure 1 has the student opening a global view of the course which is contained in the window entitled "Table of Contents." This representation is not an actual concept map, but rather a modified version of what has been termed a "map of maps" (Coffey, 2006), a structure that represents the hierarchical organization of the concept maps in the system. In this scenario, a Concept Map pertaining to XML was accessed from the course organizer map. The window containing that Concept Map is visible in the top right. From there, the student selected other information pertaining to the topic including a validation website for XML, a sample XML document that might be validated, a link to a tutorial resource on validation from Document Type Definitions, and a link to a website where an XML editor is available. The elements depicted in Figure 1 are typical of those that were included in the knowledge model used in the current study. This Study is described in the next section.

4 A Pilot Study Using a Knowledge Model to Organize and Present Course Materials

This section contains a case study in the use of the knowledge modeling scheme to develop and deliver a semester-long (4 month) course based upon a knowledge model. It starts with a description of the development process for building the model, and then elaborates research questions, methods used to deliver the course and to answer the research questions, and results of the study.

4.1 Developing and Using the Knowledge Model for the course

The initial model was created during the 5-week period before the start of the course. It was created by concept mapping chapters in a book and other background conceptual knowledge, and searching on the World Wide Web for resources with which to augment the knowledge model. Some of the accompanying resources that went into the knowledge model were identified in the book, but most were found separately through search. The top level organizer for the course, which is depicted in Figure 2, gradually emerged as a result of this process. It underwent several revisions as the course was developed. The iterative process of concept mapping and modifying the table of contents led to the structure in Figure 2.

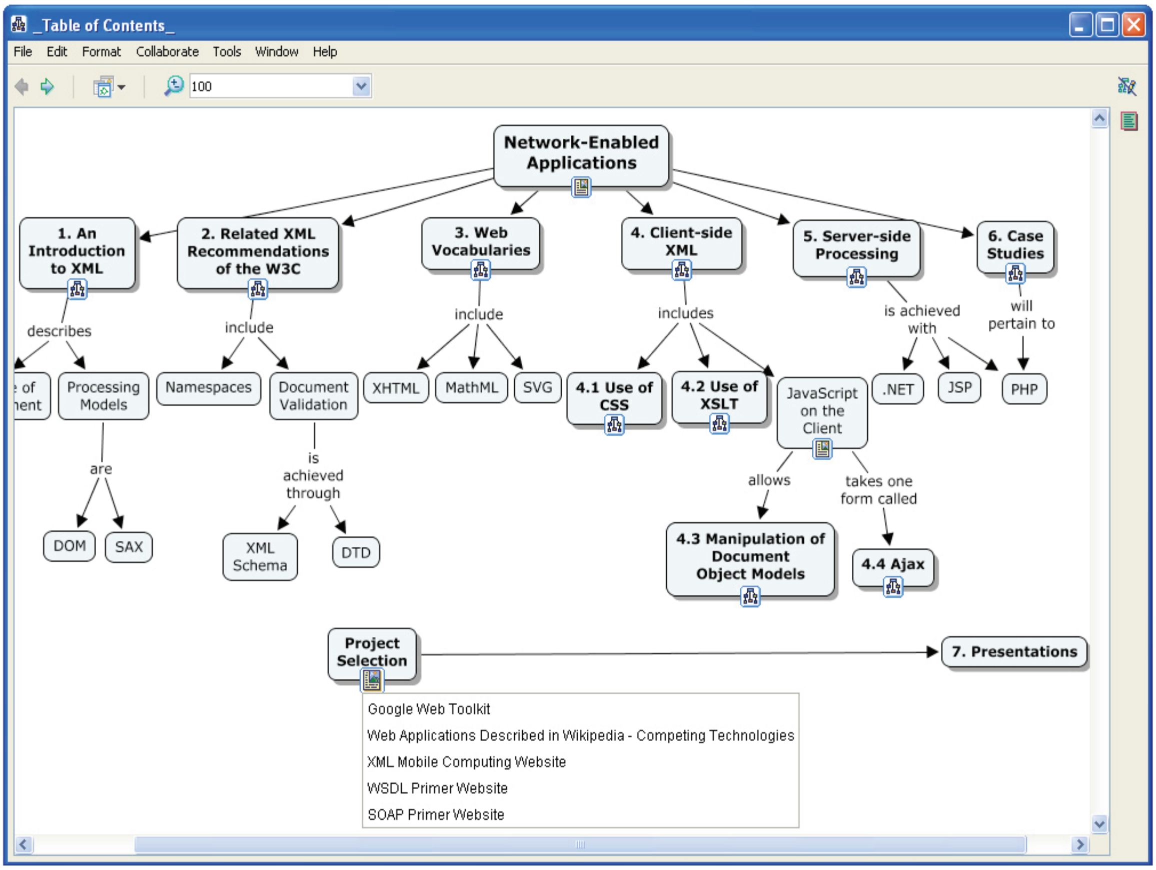

Figure 2. A graphic of the top-level page for the Web-enabled Applications course.

At the start of the semester, the Knowledge Model was placed on a *Public Cmaps* server where it was always available to the students. The instructor presented a brief introduction to Concept Maps, the structure of knowledge models, and the navigation scheme through which students access the concept maps and accompanying resources. Classes were conducted entirely through the use of the knowledge model. At the start of each class, the context of the topic of the day was discussed by viewing its place among the other topics in the organizer map for the course. After this exercise, the particulars for the day's agenda were viewed and discussed by systematically working through the relevant concepts in the concept map that pertained to the topic. This approach created a highly comprehensible broad context for the topic of the day and fostered an understanding of related, more detailed concepts.

Although this course was considered an important one to include in the curriculum, no faculty had any significant experience in these technologies. Consequently, the instructor was attempting to learn about and understand the knowledge domain as he was assembling the course. As suggested by Novak and Gowin (1984), creation of the concept maps played a very positive role in helping the instructor to understand the large amount of background knowledge needed to teach the course.

Interestingly, the process of critically assessing potential accompanying resources also played a salutary role in preparing to teach the course. The evolving knowledge model proved to be a suitable repository for the accompanying resources and it helped the instructor to keep track of them. Among others, the basic categories of resources included client and server-side program code, side-by-side comparisons of program code with the accompanying XML documents that were being processed or created, graphical depictions of software architecture, graphical depictions of processing models, online tutorials on XML, XSLT, DTD, Javascript, PHP and other technologies, and websites offering services such as the Microsoft validation website.

The room where the course was conducted contained computers for each of the students. Students typically accessed the knowledge model either from the provided computers or from their own laptops during the conduct of the class. They could modify and execute programs as the instructor did the same, visit websites linked to the materials to perform group-related active learning exercises, and perform other sorts of interactions with the course materials.

4.2 Research Questions

Four research questions were identified before the course began.

1. Would students find visual knowledge representations to be useful and/or intuitive, compared with other familiar representations of course materials?
2. How would students utilize the knowledge model?
3. Would there be any correlation between learning style and attitudes toward the knowledge modeling scheme?
4. Would the knowledge model evolve during the term, and if so, how?

4.3 Methods

A variety of methods were used to answer the research questions. Students took two surveys during the semester, one that helped to analyze their approach to learning, and a second that captured opinions regarding the use of the knowledge model as the underlying factor in material organization and course delivery. Additionally, the instructor invited students to help refine the concept maps and accompanying resources and tracked statistics on the changes that were made. The most significant changes tended to be "wordsmithing" modifications to the concepts. Changes to the knowledge model were typically based upon consensus that the change would make the model more easily understood or more easily navigable. Finally, students were invited to submit Web sites and other materials to be considered for inclusion in the knowledge model. Statistics relative to this activity were tracked.

With regard to the surveys, a 21 question, five-point Likert Scale learning style inventory that measured one basic bi-polar distinction, a predisposition to adopt either rote or meaningful learning strategies, was administered at the start of the course. Near the end of the course, a 17 question, five-point Likert Scale survey addressing the issues represented in the research questions was administered. The instructor was not involved in tallying the statistics to reassure students that they could be honest in their responses.

4.4 Study Results

The survey pertaining to the research questions included some elements to define how students used the knowledge model. A total of 92% of the students downloaded the CmapTools software to their own machines. The same percentage of students accessed the knowledge model outside class. Students had access to the book and to all code examples separately from the knowledge model, and they could easily bookmark websites that they considered useful. Accordingly, it would not have been difficult to avoid using the knowledge model at all if a student were so inclined. Statistics were also culled pertaining to accesses to documents in the model when students went in. Eight percent indicated they would typically access one document at a time, 73% stated 2-5 documents, and 19% accessed more than 5 documents at a time during an interaction with the model.

Survey Item	Agree	Disagree
The knowledge model is confusing because there are so many documents in it.	17%	67%
The main value of the concepts maps is as an organizing scheme for the other materials, rather than for the information they contain themselves.	33%	42%
I view the concept maps for the information they contain.	83%	17%
I used the concept maps to study for the exam.	58%	42%
I find it easy to find the information I want in a concept map-based knowledge model of the type used in this course	75%	8%
I prefer the organization of materials in a book to the way that they are organized in the knowledge model.	25%	25%
I would prefer to have presentations from PowerPoint than from a concept map	25%	67%

Table 1. Selected survey response rates. The scale used was (strongly agree, agree, neutral, disagree, strongly disagree). Agree is the combined number of agree, strongly agree.

Table 1 contains the most significant results of the survey. Some results are aggregated when multiple questions pertained to an issue. Percentages do not always sum to 100% because the 5 point scale allowed neutral responses. As is evident from the percentages, students did not find the knowledge model of more than 400 resources difficult to navigate. While they had somewhat mixed opinions regarding whether the concept maps were more useful for the knowledge they contained or simply as an organizing scheme, a large majority thought the concept maps conveyed knowledge even if not as large a majority used them to study for the exams. In an absolute sense, students thought the knowledge model arrangement was an effective way to organize materials. However, when compared to more traditional course organization and presentation schemes, students did not express a clear preference either for the knowledge model or the traditional approach. They did show a clear preference for presentations based upon concept maps when compared specifically to PowerPoint presentations.

Category	Count
Concept Maps	10
Total Unique Concepts	308
Average Concepts per Map	30.8
Total Propositions	357
Total Resources	397
Graphics	22
Code	285
Web Links	75
Texts	15

Table 2. Statistics pertaining to the initial knowledge model

Table 2 contains statistics pertaining to the initial knowledge model. There were a total of nine other concept maps and the course organizer map depicted in Figure 2. The concept maps contained 308 unique concepts, and almost 400 total accompanying resources, a significant majority of which were code examples. The second most commonly occurring resource type was links to other websites, not surprising with the many good tutorials, relevant standards documents, services, etc. that were pertinent to the course.

Table 3 summarizes changes to the knowledge model over the course of the semester. A total of 38 concepts were added, changed or deleted, representing 12% of the total unique concepts in the initial knowledge model. Interestingly, linking phrases, which are typically the most difficult part of a concept map to get just right, did not change at all over the course of the semester. No accompanying resources were removed from the model, and a total of 43 resources were added, increasing the number by 11%. These relatively small adjustments would suggest that, even in a relatively unfamiliar domain, knowledge modeling techniques can foster relatively rapid creation of comprehensive, well-organized course materials.

Object	Action	Occurrences	Percentage
Concepts			12%
	Add	14	
	Change	23	
	Delete	1	
Linking Phrases			0%
	Add	0	
	Change	0	
	Delete	0	
Resources			+10.5%
	Add Text	9	
	Add Graphic	7	
	Add Web Link	26	

Table 3. Statistics pertaining to changes in the knowledge model made during the course of the semester.

4.5 Student Learning Outcomes in the Course

The current study had no control group for comparison purposes. Accordingly, no statistical analyses or detailed conclusions regarding relative advantages or disadvantages of this mode of course delivery can be drawn. Nevertheless, some comments might be made regarding student learning outcomes in absolute terms using this approach. Most generally, it can be stated that student learning outcomes were not harmed by this approach. The overall grade point average (GPA) for the class, based upon the average of the final grades for the section, was 3.03 on a 4.0 point system, slightly on the high side compared with the instructor's experience in upper level elective courses. The overall average grade for three exams was 84.5%, slightly higher than for similar courses.

The examinations emphasized both high-level, integrative, conceptual knowledge (for example, compare and contrast the relative benefits of client-side versus server-side XML transformations) and more detailed programmatic problems (e.g.: analyzing a piece of computer program code to state what happens when it executes). Additionally, students performed at typical levels on programming assignments that relied both on conceptual knowledge and the ability to retrieve appropriate code examples from the model that were relevant to the problem. This course was so different from others being offered, that students could not rely on colleagues outside class to have applicable skill in debugging or useful code examples to assist them with the programs. Still, student performance was quite satisfactory on the programming component of the course.

5 Summary, Discussion, and Future Work

This article contains a description of a pilot study in the development and delivery of a course entitled "Web-Enabled Applications" using a concept map-based knowledge modeling approach as defined at IHMC. The course was a senior-level elective involving technology that was new for the instructor and students. A fundamental idea behind the organization of the course discussed in this work was to provide concept maps as advance organizers for each of the major topics in the course.

This study sheds light on the use of this approach in course development where the creation of concept maps and the knowledge model helped the instructor understand the domain and keep track of course materials. The study identified strong acceptance of this mode of course delivery including the use of concept maps in place of more traditional course presentation materials such as PowerPoint. The study suggests that, despite the students' general lack of familiarity with the organization/presentation scheme, they quickly learned to employ the representation effectively.

Future work will further the current study by exploring larger groups of students and expanded uses of the approach. A system of peer review regarding changes to the knowledge model will provide vetting of additions and modifications or materials. It is anticipated that greater participation of students in creating/enhancing knowledge models and in refining the concept maps and accompanying resources will lead to more active learning for the students and a deeper understanding of the course materials.

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A COMPARATIVE ANALYSIS ON THE USE OF CONCEPT MAPS AS AN INSTRUCTIONAL RESOURCE FOR THE GRASPING OF MEANINGS OF KEY CONCEPTS OF QUANTUM MECHANICS BASED ON THE DOUBLE SLIT EXPERIMENT

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1 Introduction

Concept maps, on a simplified way, can be considered as diagrams that show the possible linkages among given concepts related to a field of knowledge, or to a specific part of it, expliciting feasible conceptual relations and hierarchies. They were conceived by Joseph Novak and his graduate students at Cornell University, USA, in the 70s, and their use today becomes increasingly important as a strategy to facilitate meaningful learning, which was initially proposed by Ausubel and has been continuously developed by Novak and Gowin, and more recently by Moreira.

The aim of this paper is to present a comparative study of the use of concept maps as a teaching and/or learning resource or strategy. It integrates a more comprehensive research project developed by the authors on the learning of the basic concepts of Quantum Mechanics in secondary schools and in college courses that aim at the preparation of physics teachers.

Concept maps were used to show the hierarchical relations among concepts presented to students. These concepts derived from a textbook that describes the double-slit experiment with neutrons. Students were expected to unveil the hierarchical relations of subordination and superordenation that could indicate the grasping of meanings of the most inclusive concepts of the teaching content.

2 Experimental procedure - A sample

A pedagogical text was developed to describe the double-slit experiment with neutrons, which has been considered by Niels Bohr the most important experiment of quantum mechanics because it deals with its fundamental principles: complementarity, non-determinism, and wave – particle duality (Paulo, 2006).

This research was developed in three stages, in the city of Cuiabá, Mid-Western Region, Brazil. The first one started in 2001 with students of a private secondary school in three classrooms of the first year of high school and it involved 80 students. They had three weekly meetings of 50 minutes each during the first bimester of that school year, which is about 8 weeks. The average age of the students was 15, with a low level of variability, which is in agreement with the expected age average for this year of high school in Brazil. At the time, the first author was the physics teacher of that school so that she could develop her research project with a long term interaction between herself and the students—according to Novak and Gowin (1984), and Moreira and Masini (1982) this is a relevant prerequisite for offering favorable conditions for meaningful learning to occur. The use of Concept Maps as an instructional resource became an everyday practice in the classes. Step by step the students, under the guidance of the teacher got familiarized with the drawing technique and with the presentation of the maps to their peers, and this offered them relevant moments for the negotiating of meanings.

The second stage was developed in July 2006, with public school teachers taking a continuing education course with around 50 participants, average age between 30 and 50, at the Federal University of Mato Grosso (UFMT), Brazil. The introductory contents of Quantum Mechanics (QM) were developed during four weeks, morning period with a four hour period per day, in which the same text used with a previous sample was used as an introductory resource. On the other hand, during the afternoon period, the Meaningful Learning Theory, together with the construction of concept maps and V diagrams - as facilitating instruments for meaningful learning - constituted the central themes of these four weeks. The learners had, then, the opportunity of constructing concept maps on different topics of physics, so that in the QM classes the teacher could ask the students to collectively construct and analyze their concept maps.

In August 2007, the text "The Double-Slit Experiment" was once more used as a pedagogical resource in classes of the subject Structure of the Matter 1, of the course of Licenciature in Physics at the Federal University of Mato Grosso, Brazil, with a class of 18 students, whose average age was 20 with a very low degree of variability. These undergraduate students were being prepared to become high school physics teachers. After reading and discussing the text, they were asked to draw concept maps to be presented to their peers, who offered their reviews and suggestions on the maps. It seems important to emphasize that these students had not received any specific lessons on how to construct their concept maps, they just were shown some examples of maps on a diversity of topics together with brief explanations about how maps should be structured, and the learning possibilities they offered.

3 The Concept Maps

Concept Maps (CM) are instruments that agree with the Ausubelian idea that the people's mind comprises a hierarchical organization of ideas and concepts. If the maps are organized in such a way that allows for the more inclusive concepts to be at the very top of the hierarchy and the less inclusive below them, it is feasible to visualize, according to Ausubel (Moreira and Masini, 1982), movements of *progressive differentiation* (going downwards on the map) and of *integrative reconciliation* (going upwards on the map), of course this view we are using is metaphorical.

Concept maps offer evidences although frail for the comprehension of the linkages between or among the concepts involved and, possibly, of their epistemological foundations, that is, of how learners organize the various concepts they have in their minds. This feature is especially relevant here since the analysis of how quantum concepts are structured in the minds of high school students, teachers in continuing education, and undergraduate students, who are actually teachers in the initial stages of their teacher formation process, integrates the set of objectives of this study. CM might be used as tools for planning, for diagnosing conceptions held by students and teachers, and as instructional resources as well. Novak and Gowin (1984), in *Learning how to learn*, which is aimed at the classroom environment, describe how concept maps can help teaching the contents of the most diverse areas of knowledge. According to these authors, CM can be applied both to the teaching of subject matter and as an instrument for learners' evaluation. Novak's whole work attempts at convincing that concept maps, together with Ausubel's theory of meaningful learning, which underlies them, can be used in teaching practices, as a teaching-learning methodology, as well as an evaluation instrument. As it has been mentioned earlier, our emphasis here is on concept mapping as an instructional resource, and its use as instruments for evaluation ends up as a component of the teaching and learning processes of the educative event.

The teachers have to establish their own set of criteria to validate concept maps both qualitatively and quantitatively. However, it seems to us that their perception of the construction processes and the relevancy of the final product according to the proposed objectives should allow for a more adequate quantitative analysis of the concept maps. An educative event has its own particularities/features and the teacher might be the only one who knows about the development of the educational process, what the final product actually is, and whether or not the proposed objectives have been achieved. When concept maps are to be used, the set of criteria for the educative event can and should vary according to its pre-established priorities.

Drawing concept maps is a challenging educational activity for students because it requires creativity and critical thinking as far as it asks them to externalize concepts and their linkages in propositions that constitute the structure of the map itself. New linkages and meanings are constantly constructed, developed and improved. Thus, this kind of activity does not involve only those prior concepts already there in the learners' cognitive structure but it also involves the learners' skills to create and recreate new linkages, as well as new perceptions of conceptual relation.

Concept mapping as evaluation instrument, as we have already presented, requires a critical stand on the potential of CMs and a belief about the value of this activity for the construction of knowledge about a given field, in a way that might make concept maps activities differ from the usual trends in teaching and learning.

The main idea is to evaluate what the learner already knows in terms of concepts, and on how he/she structures them, organizes them hierarchically, differentiates, relates, discriminates and integrates them (Moreira, 2000). When we consider evaluation as a process, we can detect, during the drawing of the maps, aspects such as interaction with instructional material and with the work group (students and teacher), self reflectional process, which constitute steps necessary for the sharing of meanings and meaningful learning. These elements have a qualitative relevance that requires teacher's skills and common sense if we aim at a criterion-based analysis of the concept maps.

Novak and Gowin (1984) suggest a set of basic criteria for marking and assigning grades to the CMs as an attempt to a quantitative evaluation of cognitive performance concerning what should be the cognitive organization that is an outcome of meaningful learning, which involves hierarchical organization, progressive differentiation, and integrative reconciliation.

Three concept maps developed during teaching situations previously described are presented and briefly commented here, due to space limitations. They are samples drawn in class by three groups of students in the three distinct stages of schooling.

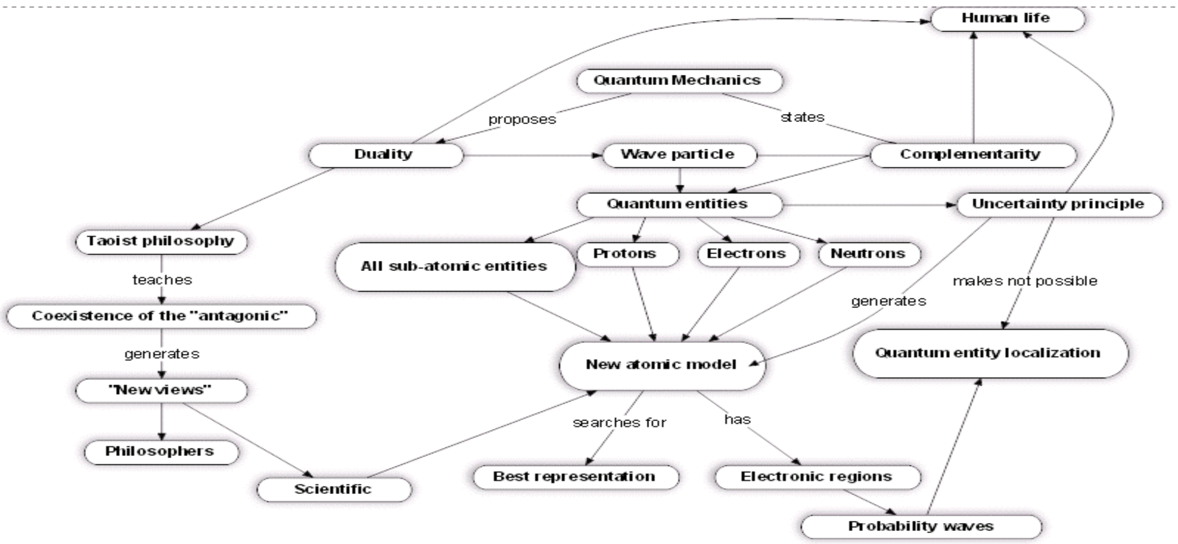

Figure 1. An example of concept map developed by a group of three students of the first year of high school.

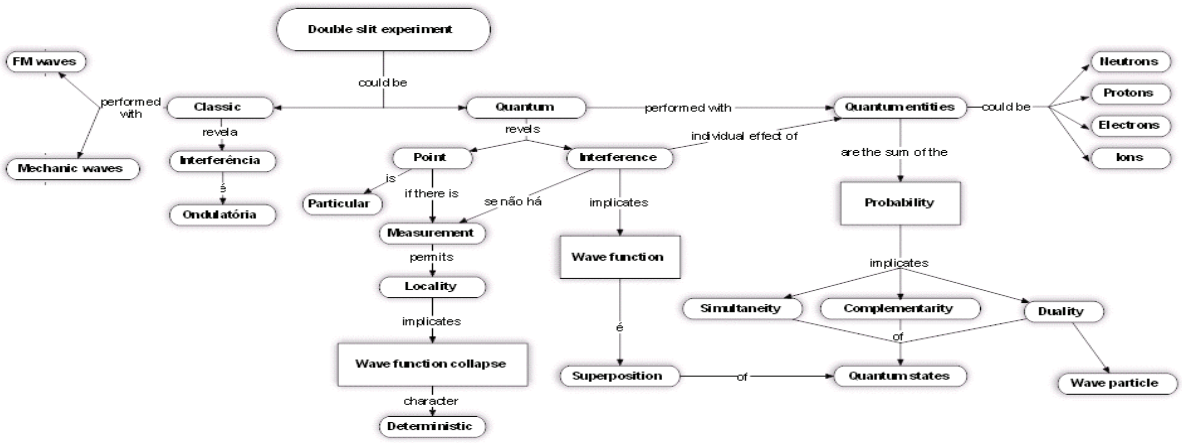

Figure 2. An example of a concept map drawn by a group of three high school physics teachers.

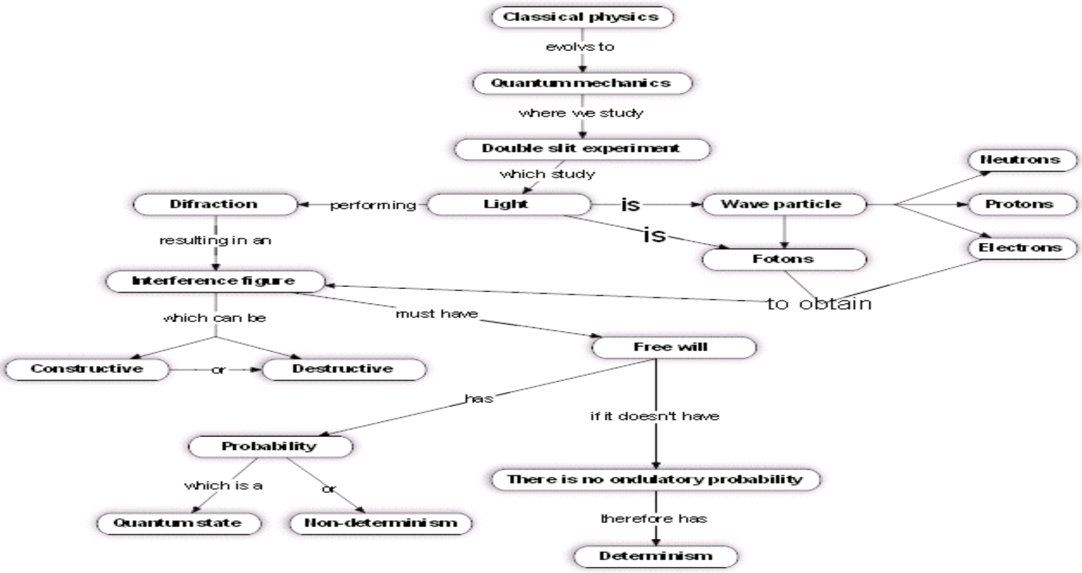

Figure 3. An example of a concept map drawn by a group of three students who are physics majors.

A pertinent fact that might be identified in these maps is that, without exception, the learners involved in this study have shown a rather sophisticated and similar conceptual organization that included the basic principles of Copenhagen Interpretation presented and discussed in the pedagogical text. Concerning morphology, we noticed that a vertical arrangement of the boxes does not necessarily mean a hierarchical organization. This can be perceived, for example, in the sequence of concets at the top of figure 1; to the left of figure 1, when Taoist philosophy is dealt with; in figure 3, it can be noticed in the concept of *classical physics*. This sort of arrangement might mean that it is a flow diagram, which constitutes another way of representing concepts, but it is not a concept map.

In all examples we can observe that students tend to hierarchically arrange concepts without organizing them vertically as a rule. Nevertheless, the hierarchical organization of concepts is a basic feature of concept mapping according to which horizontal levels of this hierarchy can present relevant relations of subordination and differentiation. As an example, in Figure 1, the concepts *light* and *wave-particle* show a subordinate relation from the perspective of science through the use of the linking verb, and it is possible to notice that this subordinate relation is valid. On the other hand, according to what might be observed in Figures 1 and 2, in the concepts wave-particles and quantum entities, respectively, we can verify that the vertical cell arrangement does not imply a hierarchical organization since it can be seen as a flow diagram. Progressive differentiation is an evident feature of concept maps, which can be an indicator of meaningful learning, however, this cannot be verified in relation to integrative reconciliation (shown only in Figure 2), suggesting that skill seems to be an ability that demands more time and conceptual maturity from the learners.

4 Final remarks

As it has been already mentioned, the examples of the concept maps present a good correlation of concepts that come close to what is expected for an initial conceptual construction of quantum mechanics. Nevertheless, whatever kind of analysis, be it quantitative or qualitative as the one performed here, does not guarantee the analysis of the concept maps to be free of any bias, since some of the difficulties become more explicit as about that a concept map might have a kind of hybrid hierarchy presenting relevant and valid linkages of subordination and differentiation. This seems to be critical according to the Novak and Gowin's criteria that privileged a hierarchical organization of concepts. In the same concept map, in some parts of it, small flow charts might appear that do not invalidate the linkages that have been established by the students between or among the concepts. The opportunities for the development of the maps and the students' oral presentations to explain them might be the most important aspect of the use of concept mapping since these spaces of critical thinking grant learners and teachers priceless educative moments of negotiating and sharing meanings about their idiosyncrasies concerning the subject matter and/or the content that has been taught. This, in turn, involves respect to diversity of opinions, ideas, and different modes of comprehension and acquisition of meanings.

A concept map reliability and its range of validity in the construction of knowledge are aspects that deserve a special attention from the teacher, taking in consideration the set of criteria he/she has established beforehand, so as to insert them as an activity of the educative event, although they can be used as an instructional resource and/or an instrument for the evaluation of constructed knowledge. Criteria may vary according to the context in which concept maps are used, and these criteria might include the hierarchical organization of concepts, crossed linkages, the existence or not of key concepts, as well as other criteria set by the teacher. The opportunity students have of experiencing the drawing a concept map and of thinking about the conceptual linkages they can come up with, and of sharing meanings with their peers stands as one of the most relevant features involved in using concept maps in the classroom as instruments with a great potentiality in facilitating meaningful learning and in getting evidences of its occurrence.

We emphasize that a relevant difference between and among the maps we have analyzed concerning their conceptual a structural quality, which can be important when we consider that the students here have come from different levels of schooling. This might indicate that the instructional material used in this research and the concepts involved in the study of the different philosophical principles of the Copenhagen Interpretation can be accessed by people of diverse levels of age and schooling.

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A CONCEPT SENSE DISAMBIGUATION ALGORITHM FOR CONCEPT MAPS

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Abstract. Concept maps are a graphically rich tool for representing knowledge in natural language. An important aspect for their automatic or semi-automatic processing, including concept mapping, formalization and evaluation, is the identification of the most rational sense of the concepts. In this paper, we present an algorithm for concept sense disambiguation based on contextual analysis, domain information and gloss. The algorithm takes advantage of the whole map's topology and use WordNet as sense repository. Results of preliminary experimental evaluations of the concept disambiguation algorithm applied to several concept maps in the Spanish language are presented and compared with the state of the art.

1 Introduction

Concept maps (CMs), defined by Novak & Gowin (1984), are a graphically-rich tool for organizing and representing knowledge in natural language. In this paper, we consider the process in which knowledge represented in a CM is automatically recognized, in such a way that it can be semantically analyzed and processed by machines. This process is related to CM formalization (e.g., Brilhante, Macedo, & Macedo, 2006; Simón, Ceccaroni, & Rosete, 2007), the automatic or semi-automatic process of CM construction (Reichherzer, Cañas, Ford, & Hayes, 1998; Cañas & Carvalho, 2004; Richardson, Goertzel, & Fox, 2006), and other processes in which WordNet (Miller, Beckwidth, Fellbaum, Gross, & Miller, 1990) is used as knowledge base in automatic CM analysis, such as the evaluation of interactive CM construction (Kornilakis, Grigoriadou, Papanikolaou, & Gouli, 2004).

CMs can be considered a structural and unrestricted knowledge representation in natural language; therefore, the identification of the more rational sense of concepts can be an interesting aspect for the automatic or semi-automatically processing of knowledge represented in CMs; for example, in the case of concepts with different meanings (ambiguous concepts), it is possible that the system suggests the automatic construction of meaningless propositions. Word sense disambiguation (WSD) (Agirre & Edmonds, 2006) has been broadly studied in the cases where documents or texts are used as context. Nonetheless, few works to solve this problem in the CM context exist; the main contribution being the one reported by Cañas et al. (2003), which shows some limitations when applied to CMs in Spanish language. We report in this work a novel algorithm for *concept sense disambiguation* (CSD), which tries to assign the more rational sense of a given concept in the CM, using WordNet (Miller, Beckwidth, Fellbaum, Gross, & Miller, 1990) as sense repository, *domain information, contextual analysis*, and *the gloss*.

Along the paper, to represent the English translation of the Spanish terms used, the following notation will be used:

español ("Spanish")

This paper begins (section 2) with an overview of the WordNet knowledge-base. Section 3 describes the main aspects considered to define the CSD algorithm, which is presented in section 4, together with an example. Results of preliminary experiments on several CMs in the Spanish language and comparison with the state of the art are reported in section 5.

2 Overview of WordNet

WordNet is a lexical knowledge-base (Miller, Beckwidth, Fellbaum, Gross, & Miller, 1990), whose basic structure is the *synset* (equivalent to sense). Synsets are distributed in form of a semantic network and interconnected among themselves by several types of lexical and semantic relations; the algorithm proposed uses WordNet's *hypernymy*, *hyponymy*, *meronymy*, *holonymy*, *gloss* and *rgloss* relations. The *synset* defines the meaning of a word, which in the case of *polysemy* can be found in various *synsets*; a meaning description (*gloss)* is included in each *synset's* structure. In addition to the *synset's* structure, general domain taxonomy (e.g.

Chemistry, Geography and Philosophy) is associated to it. The domains are associated to *synsets* in such a way that a *synset* can belong to one or several of these domains.

3 The Disambiguation Process and Concept Maps

Lexical disambiguation in its broadest definition is nothing less than determining the meaning of every word in context, which appears to be a largely unconscious process in people. As a computational problem, its solution presupposes a solution to complete natural-language understanding or common-sense reasoning (Ide & Véronis, 1998). In computational linguistics, one of the kinds of language ambiguity that have received the most attention is that of word senses: its resolution is essential for any practical application, and it seems to require a wide variety of methods and knowledge-sources with no apparent pattern in what any particular instance requires (Agirre & Edmonds, 2006). In this context, the problem is generally called *word sense disambiguation* (WSD), and is defined as the problem of computationally determining which "sense" of a word is activated by the use of the word in a particular context. WSD has been broadly studied in the case of documents or texts contexts; a review of this work is reported by Agirre & Edmonds (2006). Nonetheless, few works exist to solve this problem in CMs.

A CM is an external and simplified representation of part of a person's cognitive structure, and its obtaining is largely non language-based or language-dependent. Rather, it is a derived language from the mental imagery of the person in which ideas can be schematically represented, a feature that generally belongs to natural language. These aspects suggest that both concepts and propositions can be subject to subjectivity, which can derive in ambiguity in some cases. In CMs, WSD has been previously studied by Cañas et al. (2003). They proposed an algorithm to disambiguate the sense of words in CMs, whether they are part of a concept or a linking-phrase, using WordNet (Miller, Beckwidth, Fellbaum, Gross, & Miller, 1990). The algorithm exploits the topology of the CM, by including only the words of key concepts as part of the disambiguation process, and the semantics of the CM, by trying to determine which of the senses in WordNet best matches the context of the CM, using *hypernymy* relations from WordNet (Cañas, Valerio, Lalinde, Carvalho, & Arguedas, 2003). This algorithm was mainly defined to be applied on CMs in the English language and the results obtained with its application on several CMs in Spanish languages were less satisfactory.

In this work, we propose a *knowledge-based method* (Mihalcea, 2006) for concept sense disambiguation (CSD) in CMs, which also use WordNet as sense repository, to be mainly applied to CMs in the Spanish language. In CMs and in WordNet, a concept can be formed by a word (generally a *noun*) or several words (combination of *nouns*, *adjectives* and *verbs*); the method proposed allows disambiguating only the concepts of a CM which are included in WordNet as *synsets*. This kind of disambiguation process on CMs is generally easier than on texts; in a CM, the concepts are explicitly identified and related, while in a text these aspects are not clear and they have to be inferred. To improve the disambiguation process in CMs with respect to the one reported by Cañas et al. (2003), we maintain the contextual analysis in the CM and in WordNet, while increasing the information to take into account in the process; specifically, the use of domain information, considering the experience of Magnini et al. (2002), the gloss, and WordNet's relations such as *hyponymy*, *meronymy*/*holonymy* and *gloss*/*rgloss*, in addition to the *hypernymy* relation used by Cañas et al. (2003), were added to CSD algorithm. In it, the disambiguation process is carried out through heuristic functions, based on *domain*, *context* and *gloss*.

The **domain** constitutes a fundamental semantic property and a natural way to establish the association between concepts in a CM context (Magnini, Strapparava, Pezzulo, & Gliozzo, 2002). However, a CM integrates many domains; therefore, the most representative domains in the CM should be identified before the disambiguation. These domains are identified analyzing the occurrence frequency of the domains to which the senses of the *most inclusive, most general concepts* belong, and three alternatives have been defined to use them to disambiguate a given concept.

The **context** in which a given concept appears in the CM is explored to determine a corresponding, similar context in WordNet, using the *synset* of the concept at issue and considering the *hypernymy/hyponymy*, *meronymy/holonymy* and *gloss/rgloss* WordNet's relations. The contextual similarity provides a quantitative clue for identifying the most rational sense of a given concept, and a weight factor associated to the context created from each *synset* in WordNet is used to evaluate that similarity.

A similar analysis is carried out with the **gloss**: the algorithm evaluates the overlap between the CM context of a given concept and the context created with all words that form the glosses of the *synsets*, selecting the *synsets* of the gloss with more words in common with the CM context to disambiguate the concept. In the *contextual* and *gloss analyses*, a variable radius is used to select the concepts and words to form the CM context, allowing to take advantage of the whole CM's topology, as a novel way with respect to Cañas et al. (2003), who use two linking-phrases as a fixed distance from the concept to be disambiguated in the selection of the words to conform the CM context.

4 Concept Sense Disambiguation Algorithm

In this section, we formally describe the CSD algorithm, which comprises five steps: *preparing the CM*, *selecting a set of CM domains* (D_{cm}), *disambiguating by domain*, *disambiguating by context* and *disambiguating by gloss*. These steps are executed sequentially on a CM and the order was defined to obtain a more efficient processing. The *disambiguation by domain* required fewer queries to WordNet than the *disambiguation by context* and the precision obtained in the process is better; the *gloss* is included in the CSD algorithm as an alternative if some concepts cannot be disambiguated by domain or context. (In the Spanish version of WordNet used in this work, only a few *synsets* with gloss are available.) In the process, concepts, when disambiguated, are added to a set of non-ambiguous concepts with their senses. Before describing the algorithm, let us consider the following basic data:

- C is the set of concepts (c) in the CM;
- $S(c)$ is the set of *synset* (s) corresponding to concept c; e.g., the *synset{ser_vivo#1, ser#1, organismo#1}* corresponding to concept *Organismos* ("organism");
- $S(C)$ is the set of *synsets* corresponding to all concepts in C;
- $D(s)$ is the set of domains (d) associated to s; e.g., the domains *{Chemistry, Physics}* associated to the *synset{nitrógeno#1, número_atómico_7#1}*;
- $D(c)$ is the set of domains associated to the set of *synsets of c*;
- $D(C)$ is the set of domains associated to the set of *synsets* of all concepts in C;
- $CSD(C, d)$ is the subset of concepts in C which have at least one *synset* associated to the domain d: $CSD(C, d) = \{c_i \mid c_i \in C,\ d \in D(c_i)\}$; e.g., *CSD({Nitrógeno, Atmósfera, Tierra}, Physics) = {Nitrógeno, Atmósfera}*;
- $OF(d, C)$ is the *occurrence frequency* of domain d in the *synsets* of the concepts in C:

$$OF(d,C) = \frac{|CSD(C,d)|}{|C|} \qquad (1)$$

- $D_{ch}(D)$ is the set of child domains of the domains included in D according to the taxonomy of WordNet; e.g., D_{ch}*({Biology, Geography})={Biochemistry, Anatomy, Physiology, Genetics, Topography};*
- $D_p(D)$ is the set of parent domains of the domains included in D according to the taxonomy of WordNet; e.g., D_p*({Biology, Geography})={Pure Science, Earth};*
- $Context_{cm}(c, r)$ is the set of neighbor concepts of a given concept c within a radius r (measured as arcs between two concepts) in the CM and the words (*nouns*, *adjectives* and *verbs*) extracted from the *linking-phrases* used in the proposition in which these concepts are related;
- $Context_{wn}(s, L, C)$ is the set formed by paths between *synset s* and other *synsets s'* in WordNet, with a maximum length of L (measured as arcs between two synsets) from s, such that $s' \in S(C)$ and using *hyperonymy*, *meronymy* and *gloss* relations; e.g. $Context_{wn}$ *({agua#, H2O#1}, 2, {Hidrógeno, Oxígeno})= {({hidrógeno#1, número_atómico_1#1}, 1, 1), ({número_atómico_8#1, O#1, oxígeno#1}, 1, 1),…}*, from the paths: *{agua#, H2O#1} has_mero_madeof {hidrógeno#1, número_atómico_1#1}* and *{agua#, H2O#1} has_mero_madeof {número_atómico_8#1, O#1, oxígeno#1}*;
- $w(Context_{wn}(s, R, C))$ represents the weight of a sense s to disambiguate a concept c:

$$w(Context_{wn}(s,L,C)) = \sum_{k=1}^{|Context_{wn}(s,L,C)|} \frac{\alpha_k}{l_k} \qquad (2)$$

  where l_k is the length of the path (k) and α_k is the number of concepts in C with some *synset* in k;
- $gloss(s)$ is the set of words included in the gloss of the synset s in WordNet.

The five steps of the disambiguation process of a CM with only one most general concept are theoretically described below and applied to a practical example in section 4.1.

Step 1. Preparing the CM

Extract all concepts (c_i) and the propositions they belong to from the CM; the *proposition* set *PS* and *concept* set *CS* are created. From *CS*, the following sets are created[1]:

- the *non-ambiguous concept* set NACS = $\{c_i|c_i \in CS, |S(c_i)| = 1\}$;
- the *unknown concept* set UCS = $\{c_i|c_i \in CS, |S(c_i)| = 0\}$;
- the *ambiguous concept* set ACS = $\{c_i|c_i \in CS, |S(c_i)| > 1\}$.

Step 2. Selecting a set of CM domains (D_{cm})
Let us consider $r = 1$ and $T = 0.4$[2].
While ($|Context_{cm}(\textit{most general concept}, r)| < T * |CS|$)$\{r = r+1\}$;
$DS = D(Context_{cm}(\textit{most general concept}, r))$;
$DS_{max} = \{d_{max} \mid d_{max} \in DS, \forall d_i \in DS\ OF(d_{max}, Context_{cm}(\textit{most general concept}, r)) \geq OF(d_i, Context_{cm}(\textit{most general concept}, r))\}$;
$D_{cm} = DS_{max} \cup D(\textit{most general concept})$.

Step 3. Disambiguating by domain
For each $c_i \in$ ACS
    c_i is considered disambiguated by s_{ij} if:
        a. $|\{s_{ij}|s_{ij} \in S(c_i), |D(s_{ij}) \cap D_{cm}| > 0\}| = 1$; or
        b. $|\{s_{ij}|s_{ij} \in S(c_i), |D(s_{ij}) \cap D_{ch}(D_{cm})| > 0\}| = 1$ and $|\{s_{ij}|s_{ij} \in S(c_i), |D(s_{ij}) \cap D_{cm}| > 0\}| = 0$; or
        c. $|\{s_{ij}|s_{ij} \in S(c_i), |D(s_{ij}) \cap D_p(D_{cm})| > 0\}| = 1$ and $|\{s_{ij}|s_{ij} \in S(c_i), |D(s_{ij}) \cap D_{cm}| > 0\}| = 0$.
Update concept sets: NACS = NACS $\cup \{c_i\}$, ACS = ACS $- \{c_i\}$.

Step 4. Disambiguating by context
For each $c_i \in$ ACS
  $r = 1$;
  repeat
    $r = r + 1$; $C_t = Context_{cm}(c_i, r)$; $W_d = 0$; $S_d = \{\}$;
    for each $s_{ij} \in S(c_i)$
      if ($w(Context_{wn}(s_{ij}, L, C_t)) > W_d$), then $S_d = \{s_{ij}\}$;
        $W_d = w(Context_{wn}(s_{ij}, L, C_t))$;
      else
        if ($w(Context_{wn}(s_{ij}, L, C_t)) = w_d$), then $S_d = S_d \cup \{s_{ij}\}$;
  until ($|S_d| = 1 \vee |Context_{cm}(c_i, r)| = |CS|$)
if $|S_d| = 1$, then c_i is disambiguated with s_{ij};
Update concepts sets: NACS = NACS $\cup \{c_i\}$, ACS = ACS $- \{c_i\}$.

Step 5. Disambiguating by gloss
For each $c_i \in$ ACS
  $r = 1$;
  repeat
    $r = r + 1$; $C_t = Context_{cm}(c_i, r)$; $G_d = \{\}$; $S_d = \{\}$;
    for each $s_{ij} \in S(c_i)$
      if ($|gloss(s_{ij}) \cap (Context_{cm}(c_i, r)| > |G_d|$), then $S_d = \{s_{ij}\}$;
        $G_d = gloss(s_{ij}) \cap Context_{cm}(c_i, r)$;
      else
        if ($|gloss(s_{ij}) \cap (Context_{cm}(c_i, r)| = |G_d|$), then $S_d = S_d \cup \{s_{ij}\}$;
  until ($|S_d| = 1 \vee |Context_{cm}(c_i, r)| = |CS|$)
if $|S_d| = 1$, then c_i is disambiguated with s_{ij};
Update concepts sets: NACS = NACS $\cup \{c_i\}$, ACS = ACS $- \{c_i\}$.

[1] The senses of the concepts are found using WordNet, after applying a morphological transformation where needed. The transformation simply consists in obtaining the singular form of the concept if it appears in plural.
[2] Coefficient T defines the percentage of concepts in the CM, to be considered for determining the CM's domains.

4.1 An example

As an example, we apply the CSD algorithm to a CM in Spanish about *Nitrógeno* (“nitrogen”), shown in Figure 1; its English translation is shown in Figure 2. A Spanish version of WordNet[3] was used as sense repository.

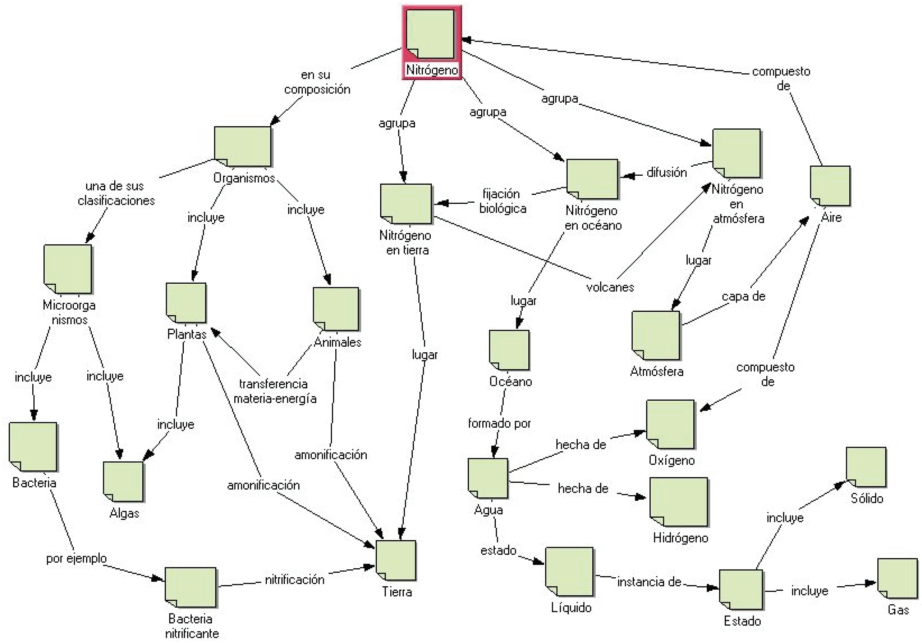

Figure 1. Concept map of *Nitrógeno* (“nitrogen”), in Spanish

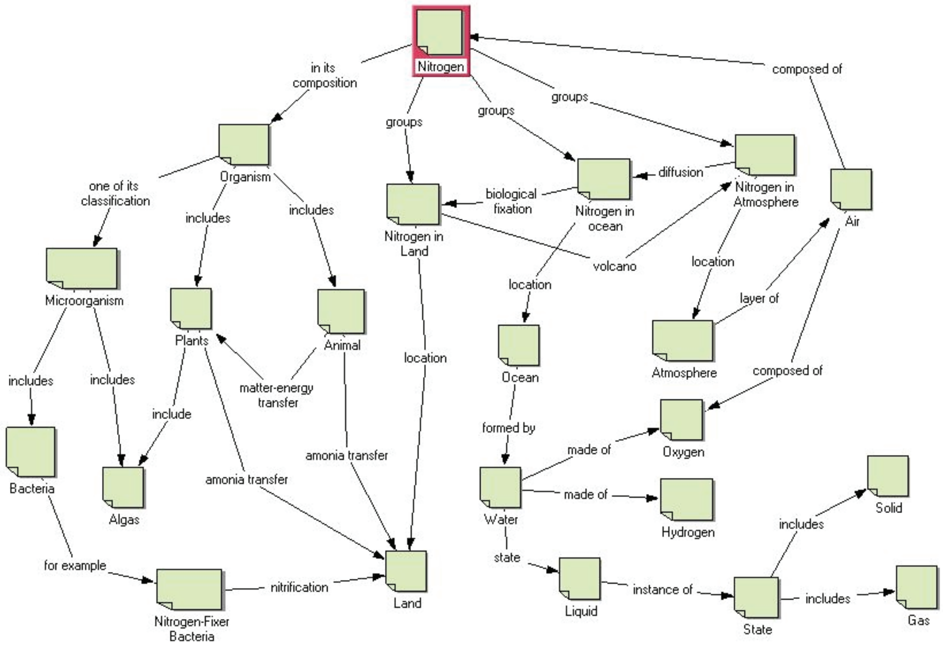

Figure 2. Concept map of the *Nitrógeno* (“nitrogen”), in English

In **Step 1**, all *concepts* and *propositions* are extracted and 11 ambiguous concepts (50%), eight non-ambiguous concepts (30%) and four unknown concepts (20%) are identified.

In **Step 2**, 21 domains are identified in WordNet from the synsets corresponding to the 19 ambiguous and non-ambiguous concepts; from these WordNet domains, *Chemistry, Physics, Biology, Geography,* and *Astronomy* are identified as CM domains.

[3] Concretely, the version developed by the Natural Language Processing Group (TALP) of the Software Department (LSI) of the Technical University of Catalonia (UPC) (Farreres, Rigau, & Rodríguez, 1998).

For the disambiguation-by-domain (**Step 3**), we consider the ambiguous concept *Organismo* ("organism") with two *synsets* in WordNet: *1-{organismo#1, ser#1, ser_vivo# }: Biology –cualquier entidad viva* ("any living entity") and *2-{organismo#2}: Factotum –entidad pública o privada con una función determinada* ("a system considered analogous in structure or function to a living body"). The concept is disambiguated with the *synset 1-{organismo#1, ser#1, ser_vivo#}* using the *Biology* domain.

For the disambiguation-by-context (**Step 4**), we consider the concept *Agua* ("water") with five *synsets* in WordNet: *1-{H2O#1, agua#1}*: *Chemistry*, *Geography –líquido incoloro, insípido e inodoro* ("a clear colorless odorless tasteless liquid"), *2-{agua#2, systema_de_aguas#1}*: *Hydraulics - fuente de agua* ("source of water"), *3-{agua#3, masa_de_agua#1}*: *Geography-parte de la superficie de la Tierra cubierta de agua* ("the part of the earth's surface covered with water"), *4-{agua#4}*: *Philosophy - antes, considerada uno de los cuatro elementos que formaban el universo* ("once thought to be one of four elements composing the universe") and *5-{agua#5, agua_de_lluvia#1, lluvia#2}*: *Factotum- gotas de agua fresco que caen como precipitación desde las nubes* ("drops of fresh water that fall as precipitation from clouds"). The algorithm first selects the concepts and words from the *linking-phrases* to form the CM context: *Nitrógeno en Océano* ("nitrogen in ocean"), *Océano* ("ocean"), *Oxígeno* ("oxygen"), *Hidrógeno* ("hydrogen"), *Líquido* ("liquid"), *Aire* ("air"), *Estado* ("state"), *hecha* ("made"), *formado* ("formed"), *instancia* ("instance"), *lugar* ("place"), *compuesto* ("composed"). Then, the paths between the *synsets* of these concepts/words and each *synset* of *Agua* ("water") in WordNet (that is, the context in WordNet associated to the CM context) are selected: 142 paths from *synset-1* ($w = 150$), 18 paths from *synset-2* ($w = 22$), 59 paths from *synset-3* ($w = 69$), 20 paths from *synset-4* ($w = 20$) and 11 paths from *synset-5* ($w = 11$). Therefore, the concept *Agua* ("water") is disambiguated with the sense identified by the *synset1-{H2O#1, agua#1}*, which is the correct sense of the concept in this context.

The rest of ambiguous concepts is disambiguated either by domain or context and the disambiguation by gloss (**Step 5**) is not necessary in this case. The algorithm proposes only one incorrect sense, achieving 90% of precision.

5 Experimental Results

For the experimental process, the same Spanish version of WordNet used in the example in section 4.1 was used as sense repository, and the metrics *precision* [4](PR), *recall*[5] (RE) and *coverage* (CO) (Palmer, Ng, & Dang, 2006) were used to measure the results, which was possible because the correct sense corresponding to the ambiguous concepts was known. We started the tests selecting 20 CMs from the literature, validated by experts and with *at least one ambiguous concept* (according to WordNet). These CMs had, in average, 17 concepts each (81% of the concepts had at least one synset in WordNet), and 16 domains each. All ambiguous concepts in those CMs were included in the evaluation set (a total of 151) and they had an average number of five *synset,* which belonged to more than 30 domains. Two kinds of tests were carried out with the CSD algorithm: (1) the *whole algorithm* was applied to the evaluation set (The results for each CM are shown in Table 1.), and (2) each part (*domain, context* and *gloss*) of the algorithm was independently applied to the evaluation set. (The general results are shown in Table 2.) The CSD algorithm guessed some sense tag in 151 cases (100% of coverage) and the correct sense tag in 135 cases, achieving 89,4% of precision and recall.

The *precision* results obtained in the second test confirm the potential usefulness of domain, gloss and the use of other WordNet's relations, such as *meronymy/holonymy*, in addition to the *hypernymy* relation used by Cañas et al. (2003), in the concept disambiguation process in CMs. Nonetheless, low results were obtained for *recall* and *coverage* when only the domain information or the gloss were used in the disambiguation process. In the first case, this was due to several *synsets* of a same concept being associated to the same domain in WordNet; rendering thus the domain a less disambiguating factor. In the second case, it was due to the few *synsets* with gloss found in WordNet.

To compare the CSD algorithm with the one reported by Cañas et al. (2003), eight CMs were selected from the 20 used in the previous tests, where all ambiguous concepts were formed by one word. Cañas et al. (2003)

[4] The precision of a system is computed by summing the scores over all test items that the system guesses on, and dividing by the number of guessed-on items.

[5] Recall (or accuracy) is computed by summing the system's score over all items (counting unguessed-on items as zero score), and dividing by the total number of items in the evaluation set.

selected for evaluation one-word concepts that had more than two senses in WordNet. The same version of WordNet from previous tests was used to evaluate both algorithms and the results are shown in Table 3.

Maps	DC[a]	DI[b]	ND[c]	Step 3 (D)		Step 4 (C)		Step 5 (G)		PR	RE	CO
				DC	DI	DC	DI	DC	DI			
1	12	1	0	3	1	9	0	0	0	0,923	0,923	1,000
2	5	0	0	3	0	2	0	0	0	1,000	1,000	1,000
3	10	0	0	5	0	5	0	0	0	1,000	1,000	1,000
4	10	1	0	6	0	4	1	0	0	0,909	0,909	1,000
5	4	1	0	3	0	1	1	0	0	0,800	0,800	1,000
6	6	2	0	2	0	4	2	0	0	0,750	0,750	1,000
7	9	1	0	2	0	7	1	0	0	0,900	0,900	1,000
8	2	0	0	1	0	1	0	0	0	1,000	1,000	1,000
9	4	1	0	1	0	3	1	0	0	0,800	0,800	1,000
10	3	0	0	1	0	2	0	0	0	1,000	1,000	1,000
11	4	0	0	1	0	3	0	0	0	1,000	1,000	1,000
12	1	1	0	0	0	1	1	0	0	0,500	0,500	1,000
13	9	1	0	4	1	5	0	0	0	0,900	0,900	1,000
14	4	1	0	1	0	3	1	0	0	0,800	0,800	1,000
15	10	1	0	2	0	8	1	0	0	0,909	0,909	1,000
16	2	1	0	1	1	1	0	0	0	0,667	0,667	1,000
17	12	0	0	4	0	8	0	0	0	1,000	1,000	1,000
18	9	1	0	2	0	7	1	0	0	0,900	0,900	1,000
19	15	2	0	10	1	5	1	0	0	0,882	0,882	1,000
20	4	1	0	3	0	1	1	0	0	0,800	0,800	1,000
Total.	**135**	**16**	**0**	55	4	80	12	0	0			
Ave.	6,75	0,8	0	2,75	0,20	4,00	0,60	0	0	**0,872**	**0,872**	**1,000**

[a] **DC**: correctly disambiguated concepts ; [b] **DI**: incorrectly disambiguated concepts ; [c] **ND**: non disambiguated concepts

Table 1: Experimental results obtained with the whole CSD algorithm

Parts of the algorithm	PR	RE	CO
Domain	**0,945**	0,352	0,381
Contextual analysis	**0,841**	**0,841**	**1,000**
Gloss	**0,838**	0,253	0,327

Table 2: Experimental results obtained by each part of the CSD algorithm, applied independently

Maps	Ambiguous Concepts	Cañas et al. (2003)'s algorithm						CSD algorithm					
		DC[a]	DI[b]	ND[c]	PR	RE	CO	DC	DI	ND	PR	RE	CO
1	5	0	5	0	0,000	0,000	1,000	5	0	0	1,000	1,000	1,000
2	10	8	2	0	0,800	0,800	1,000	10	0	0	1,000	1,000	1,000
3	8	3	5	0	0,375	0,375	1,000	6	2	0	0,750	0,750	1,000
4	2	2	0	0	1,000	1,000	1,000	2	0	0	0,800	0,800	1,000
5	2	1	1	0	0,500	0,500	1,000	1	1	0	0,500	0,500	1,000
6	12	8	4	0	0,667	0,667	1,000	12	0	0	1,000	1,000	1,000
7	17	11	6	0	0,647	0,647	1,000	15	2	0	0,882	0,882	1,000
8	5	4	1	0	0,800	0,800	1,000	4	1	0	0,800	0,800	1,000
Total.	**61**	**37**	**24**	0				**55**	**6**	**0**			
Ave.	7,62	4,62	3,00	0	**0,599**	**0,599**	**1,000**	6,87	0,75	0	**0,842**	**0,842**	**1,000**

[a] **DC**: correctly disambiguated concepts ; [b] **DI**: incorrectly disambiguated concepts ; [c] **ND**: non disambiguated concepts

Table 3: Comparison between the Cañas et al. (2003)'s proposal and the CSD algorithm

The results obtained from the evaluation set selected suggest a significant improvement by the CSD algorithm with respect to the one reported by Cañas et al. (2003) on CMs in Spanish, and confirm the usefulness of increasing the information considered for the disambiguation process.

6 Conclusions

A concept sense disambiguation algorithm to apply in automatic or semi-automatic processing of concept maps, which uses WordNet as sense repository, has been presented. The algorithm defined explores the context in which the concepts appear in a concept map, and tries to determine which context in WordNet has the best similarity with the context defined in the concept map. This contextual similarity, combined with domain and gloss analysis, allows improving the accuracy of disambiguation of concepts in concept maps in the Spanish language, providing better results with respect to similar research, using the same evaluation set.

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A CONCEPT-MAP MODELING APPROACH TO BUSINESS PLANNING IN A COMPUTER ENVIRONMENT

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Abstract. We have studied widely business planning in our Learning Business Planning Project. This approach emphasizes the role of creativity in business planning. Concept maps are used in this context in our theory and concept formation, in the user interfaces of our Internet applications and in decision making modeling and simulations. In the last application area we have combined the methods of concept and cognitive maps as well as computational intelligence in order to provide good systems in a computer environment. An example of this combination is provided.

1 Introduction

This paper considers such novel approach to business planning which emphasizes invention and innovation processes when new business ideas are created. Our ultimate aim is to provide new proactive and innovative resolutions for designing a computer simulation tool for learning business planning. Our economical and behavioral-scientific theories stem from the ideas suggested by [2] and according to them, instead of conducting the traditional business planning, we should be more creative and flexible as well as we should focus more on invention and development of business ideas. In our theory formation and computer simulation we apply concept and cognitive maps as well as the methods of computational intelligence.

Our approach was studied in our *Learning Business Plan Project* (LBP Project) in 2005-2007. This project models the invention of business ideas by combining theories of on creativity in order to provide a new proactive and innovative resolution for learning business planning. Our approach also combines certain philosophical ideas and the actual behavior of the human being [7].

We thus assume that human intelligence is creative and capable of interacting with reality, and these assumptions lead us to certain methodological and theoretical choices in our model construction. We use concept mapping when establish these bases. We also use concept mapping in our model construction and simulation. Hence, concept maps are used at both meta and object level of our studies. In practice we make both concept and cognitive map configurations on the business planning problems of the real world, and then we construct the corresponding computer models in order to simulate our phenomena [8] (Fig. 1).

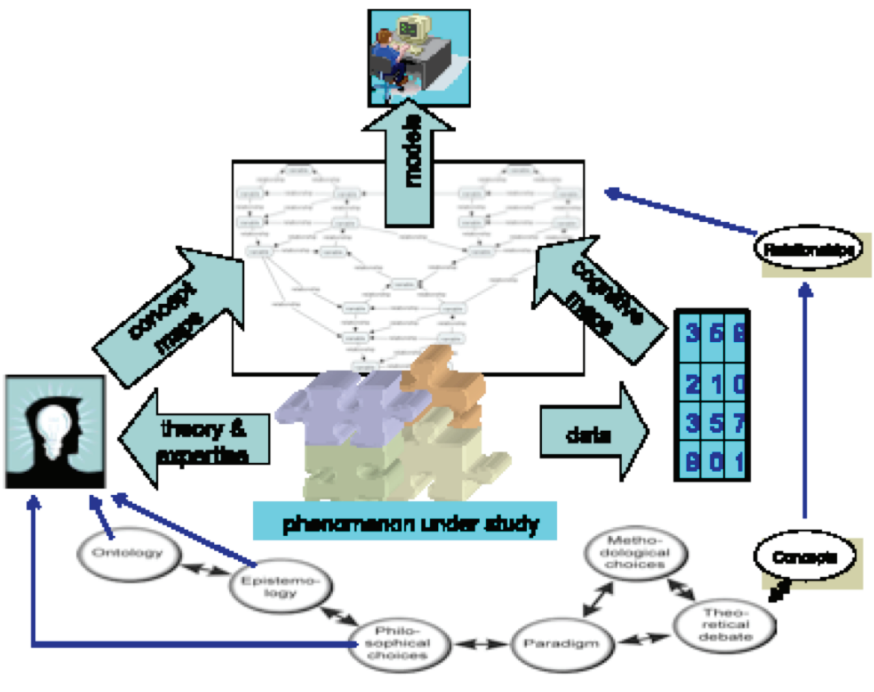

Fig. 1. The General Framework for Our LBP Modeling.

Below we introduce our approach which combines our theories and computer simulations. We also provide two simplified examples which hopefully illuminate how we will proceed in practice. Section 2 briefly introduces the theoretical basis of our project. In Section 3 we briefly present the concept map approach to our meta level work. Sections 4 and 5 provide examples on concept maps in our computer simulations. Section 6 concludes our considerations.

2 Theoretical Basis of the LBP Project

The problems and limitations of the traditional business planning can be subsumed under three categories:

1. Business planning is regarded as an objective, isolated phenomenon excluding individual competences and contribution as well as creativity, motivation and volition, thus also excluding individual and contextual factors and processes as well as innovativeness
2. Its normative and static form follows a linear and rational logic and focuses on an existing idea and situation also excluding innovative learning and development
3. It assumes that business planning and consequently learning is a static and functional series of operational planning activities.

These core features are contradictory to those theories of entrepreneurship that stress the innovative abilities and processes, opportunity recognition, creation and exploitation as well as the complex and complicated context of entrepreneurial processes. The findings of [2-5 on the ineffectiveness of business planning may actually derive from these core features of traditional business planning and set business planning apart from the entrepreneurship theory discussion, which also justifies the criticism in [2] regarding the lack of creativity in teaching business planning. Thus in order to advance the modeling and teaching of business planning, we should be able to these limitations. First we need to find a way to model business planning that follows the core aspects and dynamics of entrepreneurial behavior and processes. Then we should be able to find an approach to teaching it. In both of these problems we have benefit from concept mapping approach and technique. Figure 2 demonstrates how the overall model has expanded from financial calculations toward creative learning process.

At stage 1 we provided configuration paradigm that follows the human being as a unique, holistic and creative individual capable of inventing and generating business ideas and activities in complex and complicated environments. This resulted five-stage business planning model.

Stage 2 added the zones of creativity in business planning into stages 1 and 2. Stage 3 provided solution for stage 3 by using concept mapping methods. Stage 4 integrated processes by segmentation of stage 3 into three sub-stages and solving the implementation of the construction in two layers and as a transformation processes between these two. Stage 5 conceptualized distinct feasibility studies integrating linguistic and numeric information by using concept map technique.

3 Meta Level Concept Mapping

At the meta level we apply concept maps somewhat in the standard manner [9]. We use them in theory and concept formation and in flowcharting the general configurations of our system. In this manner we can obtain a good general view on our system, find its possible inconsistencies and disadvantages and enhance it if necessary. We can also perform tentative computer simulations at this level already by applying the methods in section 3 and 4.

When our concept map modules are implemented as a website to the Internet server, from the customer's standpoint they obviously facilitate the understanding of the causal structures and the contents of instructional materials when an appropriate user interface is constructed. Thus, in the context of the www applications, the concept maps are useful for us when such ubiquitous computing and e-learning techniques as hypermedia, semantic web and theory of networks are utilized.

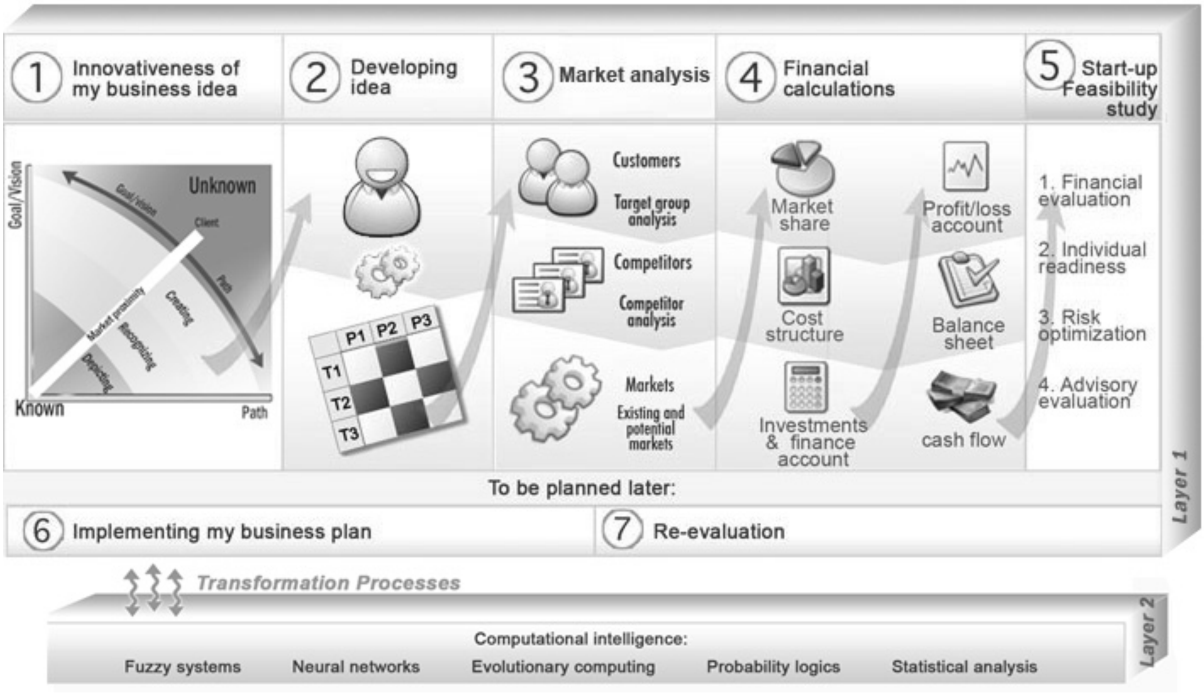

Fig. 2. General View on the LBP Project.

4 Concept and Cognitive Maps in Computer Simulation

To date it has been problematic to operate with such theoretical frameworks and model simulations in a computer environment as was mentioned above because they include a great number of concepts and various interrelationships between these them. In brief, the quantitative methods are unable to cope with the linguistic and approximate values and relationships, whereas the qualitative methods are principally based on manual work and human reasoning. By virtue of such methods of computational intelligence as fuzzy systems, neural networks and evolutionary computing, we can resolve several of the foregoing problems because, in addition to numerical methods, these methods enable us to construct such simple models which use human-like reasoning and operate with both linguistic and approximate concepts and relationships [11]. We can thus apply both quantitative and qualitative methods in combination in our studies and our results correspond well with human reasoning.

In practice our configurations can base on both human expertise and empirical data. In the former case we thus operate with a priori concept maps, whereas in the latter case a posteriori maps can be used. In the a priori maps we specify the concepts and establish their interrelationships according to our intuition and expertise and their evaluations are also based on our reasoning. Consider the simple configuration in Figure 3 [10]. It includes seven concepts or nodes which in our case are often numerical or linguistic variables, i.e., their values numerical or linguistic (e.g., *5*, *about 5*, *very high*). The interrelationships, in turn, are mathematical functions of several variables or linguistic rule bases. The former case is analogous to regression equation specification, and the rule bases usually apply fuzzy reasoning.

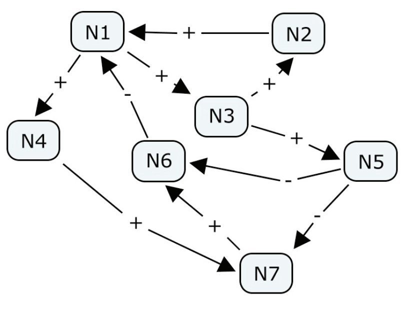

Fig. 3. An Example of a Simple Configuration.

In Figure 3 we first use two types of simple relationships, *x increases y* (+) and *x decreases y* (-), and we thus have a rough configuration of our system. Then we proceed by establishing more concrete relationships. For example, given the concepts 2, 6 and 1, we can generate such rules as

1. *If N2 is low and N6 is low, then N1 is medium.*
2. *If N2 is low and N6 is high, then N1 is fairly low.*
3. *If N2 is medium and N6 is low, then N1 is fairly high.*
4. *If N2 is medium and N6 is high, then N1 is medium.*
5. *If N2 is high and N6 is low, then N1 is high.*
6. *If N2 is high and N6 is high, then N1 is fairly high.*

By using fuzzy reasoning methods with this rule base, we can obtain such model for this relationship as depicted in Figure 4. Since the similar method can be applied to all concepts, we obtain a configuration which can be simulated in a computer environment (Fig. 5). For example, we can then consider the behavior of our map in various conditions by assigning initial values to the concepts or we can provide such *what-if* questions as *What happens in the network if N3 is initially fairly low?* Hence, concept mapping enables us to consider complicated networks of events or phenomena with computer models.

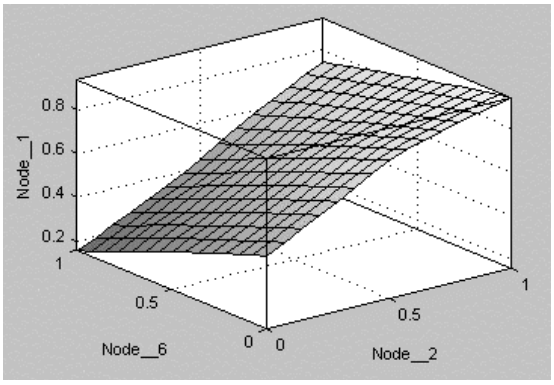

Fig. 4. Fuzzy Reasoning Model Based on the Foregoing Rule Set.

In a posteriori configurations, in turn, we operate with data sets. If numerical data is available, we perform the foregoing constructions “automatically” by using evolutionary computing, in particular the genetic algorithms. These methods provide as with the appropriate rule bases and they can even select relevant concepts to our configurations. In the case of non-numerical data it is possible that first we have to perform some modifications or transformations to them.

By virtue of computational intelligence, we in fact combine two methods, concept and cognitive mapping [1,6,10]. The latter has already been used in fuzzy modeling to some extent but in most cases in a pure numerical form in dynamical systems. In this respect it is only an application of a directed numerical graph from the mathematical standpoint. However, there are also some linguistic versions available and these are applied to our approach. Hence, concept mapping provides us with a tool for representing our ideas and theories fluently, whereas by transforming these configurations into cognitive maps, we can apply better computational intelligence in concept and theory formation and in particular in model construction. These maps also allow us to use feedback (loops) in our models, and these operations are not possible with the Bayesian networks. In this manner we are unable to utilize fully the capabilities of the concept maps but in our decision making and decision supporting systems the foregoing approach seems to be justified.

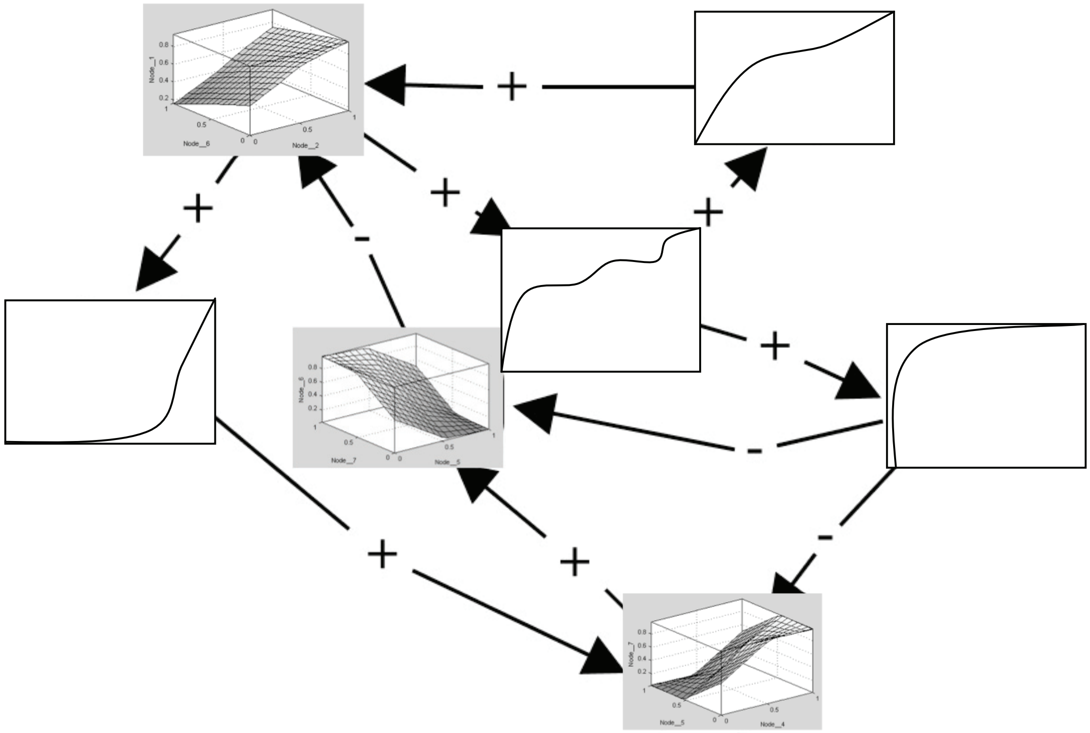

Fig. 5. A Tentative Modeling According to Fig. 3.

5 Example of LBP Modeling

Below we sketch a model which deals with market segmentation in the LBP system and in this context we apply the configuration depicted in Fig. 6.

When an entrepreneur considers his/her business idea by using our planning matrix at stage two (Fig. 2), he/she is expected to make certain assessments on the customers, products and services. Given the target group of customers and the product or service, the system uses such variables as their benefit matching, buying profiles and psychological profiles are constructed (Fig. 7).

The psychological profile constitutes variables which measure such customer's traits as interests, values, attitudes and lifestyle. Buying profile includes gender, age, education, socio-economical status, brand loyalty, product usage rate, etc. Benefit matching, in turn, is obtained according to the target group's benefit sought, readiness for buying and income. We provide a tentative model for the third case.

We thus have four variables as follows:

1. Benefit sought: by using the scales with the extremes low - high, we measure the degree of similarity between the entrepreneur's and target group's opinions on the economic / non-economic benefit assigned to the product or service. The more similarity, the better for the benefit matching (and for the business plan).
2. Readiness for buying: we use the extremes not ready - ready when we assess target group's readiness to buy the given product or service. The more readiness, the better for the benefit matching.
3. Income: the degree of similarity (low - high) is measured when the target group's income and the entrepreneur's estimate on an appropriate target group income for the product are compared. The more similarity, the better for the benefit matching.
4. Benefit matching: reveals the goodness of the entrepreneur's assessments. The more matching, the better.

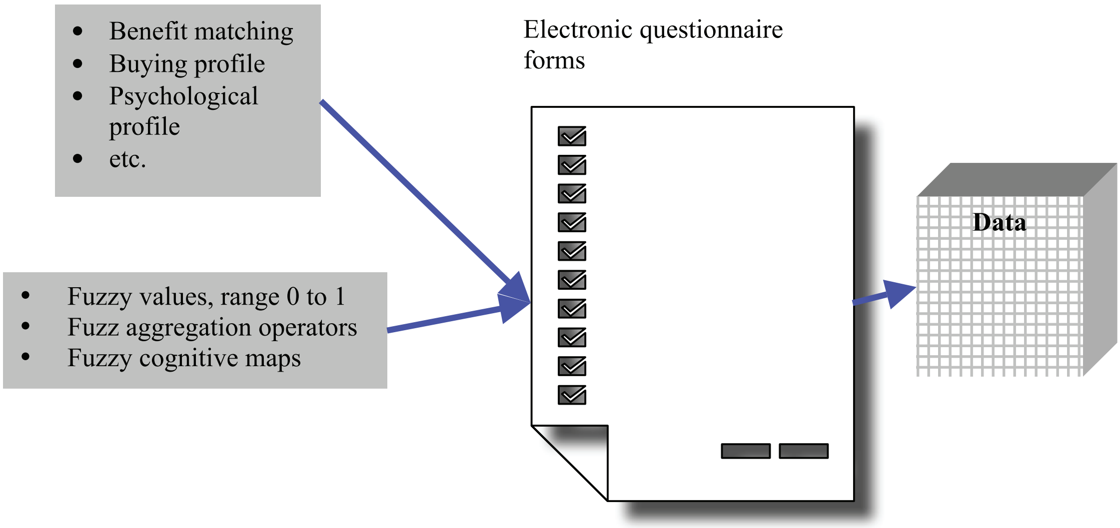

Fig. 6. Excerption from Business Plan Analysis at Stage 2.

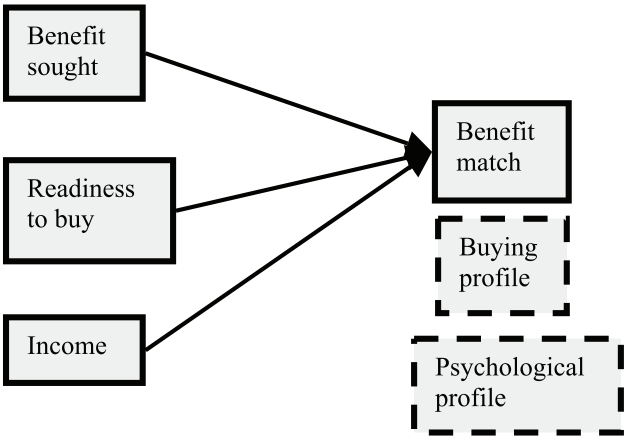

Fig. 7. An Example of Fuzzy Modeling.

Our linguistic scales constitute the extreme values, the linguistic modifiers of these values (very, fairly, etc.), and a midpoint value (e.g. medium). In our model we use the linguistic scales

extreme1 - fairly extreme1 - medium - fairly extreme2 - extreme2

For example,

low - fairly low - medium - fairly high - high

In our reasoning model we presuppose that, first, the outputs should be average aggregations of the possibly weighted inputs; second, compensation should be taken into account; third, high input values should yield high output values and vice versa; and finally, if at least one input variable has the minimum value, the minimum output value should be obtained.

If we obey these metarules, we can generate for our reasoning system such fuzzy rules as

1. If the similarity in benefit sought is low and readiness to buy is not ready and similarity in income is low, then benefit match is low.

2. If the similarity in benefit sought is low and readiness to buy is ready and similarity in income is high, then benefit match is low.
3. If the similarity in benefit sought is medium and readiness to buy is between ready and not ready and similarity in income is medium, then benefit match is medium.
4. If the similarity in benefit sought is high and readiness to buy is ready and similarity in income is high, then benefit match is high.

Fig. 8. Depicts the variation of the outputs in the case of two input variables, benefit sought and income, when a constant value is assigned to readiness for buying. Similar output surface is obtained if alternative input pairs are used in the figure because of the symmetric nature of our model.

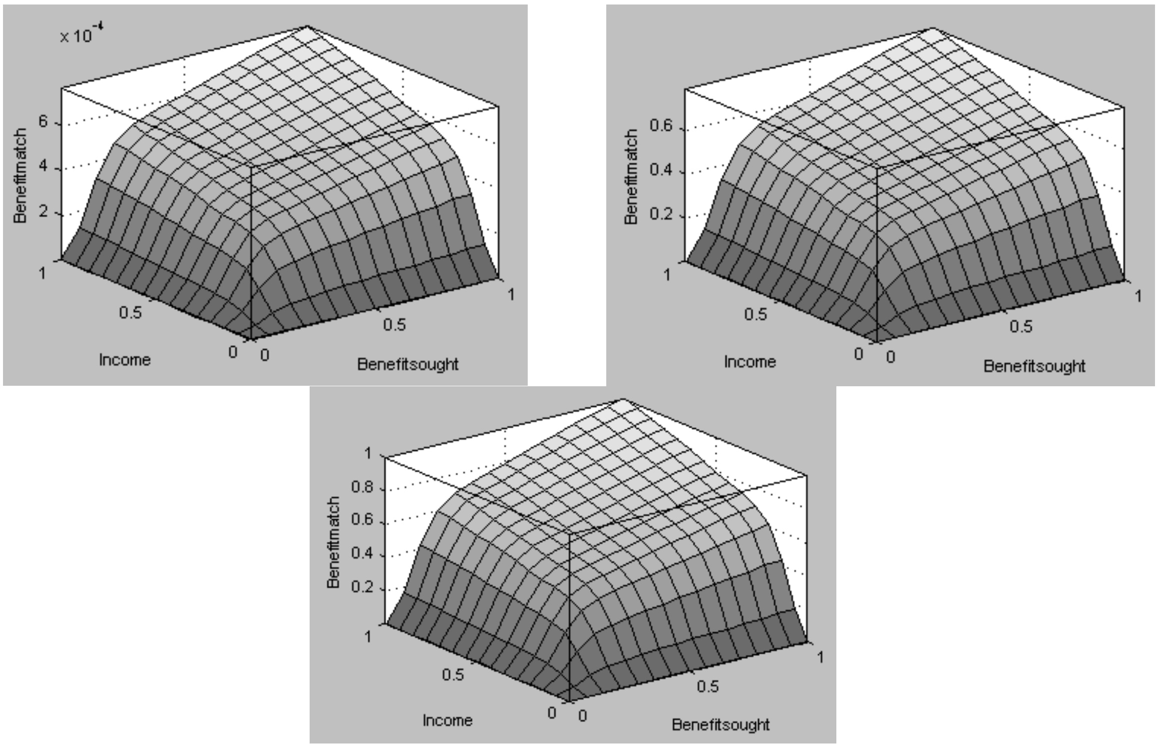

Fig. 8. Benefit Match Model with Two Varying Inputs and when Readiness for Buying Is Not Ready (top left), between Ready and Not Ready (top right) and Ready (bottom).

This example shows us that we can construct reasoning models effortlessly in our LBP Project when we apply computational intelligence and concept and cognitive maps. First, we can model even complicated causal networks in business planning with these maps, and, second, only indicative and approximate linguistic metarules are required that we can construct the causal connections between the system variables with fuzzy reasoning. By virtue of our linguistic approach we can use more versatile interrelationships between the variables than those used within the purely numerical methods. We can also apply qualitative techniques in a computer environment, and this task has been problematic before. Naturally, the foregoing example will only be one constituent in a large concept map representing our LBP system.

6 Summary

We have examined business planning in our LBP project in 2005-2007. This project models the invention of business ideas by combining theories of on creativity in order to provide a new proactive and innovative resolution for learning business planning. Our approach also combines certain philosophical ideas and the actual behavior of the human being.

We have used concept maps to our meta level considerations, user interfaces in the Internet and reasoning and simulations in our decision models. In the first area concept maps are used for theory and concept formation. In the second area these maps are applied to ubiquitous computing. In the third area we have used the idea of concept mapping when we have constructed decision making and decision support models in a computer environment. In this context we have also applied the methods of computational intelligence as well as we have transformed our concept maps into the corresponding cognitive maps if necessary.

We have recognized that concept mapping and computational intelligence are usable for our examinations because we operate with complicated systems which constitute a great number of concepts and both numerical and linguistic variables and interrelationships.

7 Acknowledgements

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Concept Mapping: Connecting Educators
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A DESIGN EXPERIMENT IN ELEMENTARY SCIENCE LESSON USING CONCEPT MAPPING SOFTWARE FOR RECONSTRUCTING LEARNING PROCESSES: CONCEPTUAL UNDERSTANDING OF "THREE STATES OF MATTER"

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Abstract. In this study, we improved a science curriculum that was developed in 2004 using Concept Mapping Software for Reconstructing Learning processes, and introduced into a new lesson in 2006. The result of comparative analysis between two lessons showed that students in the lesson in 2006 had more deep understanding than the students in the lesson in 2004. Furthermore, teachers' evaluation revealed that this curriculum improvement was effective to support students deepen their scientific understanding.

1 Introduction

Concept maps (Novak & Gowin, 1984) are widely used in educational researches and practices to support externalizing the knowledge and thought of the learner. Recently, various software to create concept map on the computer have been developed (e.g. Cañas *et al*., 2004).

Inagaki *et al.* (2001) developed a concept mapping software to support externalizing learners' thinking process. Exploiting the digital computer technology, this software saves all operations, such as erasing or rearranging labels and links, and is able to play back the concept mapping process whenever necessary, even in the middle of the concept mapping. This function has been evaluated as a strong tool to support learners' reflection and dialogue.

This software has been introduced into many experimental lessons. For example, Daikoku *et al.* (in press) introduced this software into a junior high science lesson, and evaluated the effectiveness of using the software in collaborative learning environment. Deguchi *et al.* (2006) and Deguchi *et al.* (2007) showed that the bookmarking function of the software, a function to mark the specific points of all the concept mapping process, could support students reflection and dialogue.

In these experimental lessons, the effectiveness of the software to support learning has been revealed, but consecutive evaluation and improvement of the curriculum using this software have not conducted. Once a curriculum developed, it has to be refined and repeatedly introduced into actual lessons. Through such a research, it will be able to clarify the important points, that means design principle, in introducing concept mapping software into school lessons. From the viewpoint of design experiment, it could be noted that, such a curriculum introducing information technologies have to be consecutively improved to create a better learning environment (Brown, 1992).

In this study, we improved the curriculum using the software that was held in an elementary science lesson in 2004, and conducted a new lesson in 2006. Additionally, we had a comparative analysis and questionnaire based survey in order to evaluate the improvement of the curriculum.

2 Concept Mapping Software for Reconstructing Learning Process

Figure 1 shows the user interface of the concept mapping software for reconstructing learning processes. Text labels can be placed anywhere by dragging and dropping from the text label template to the desired position in the layout area. Images such as photos can be also placed in the concept map, as shown in Figure 1. To create a link, click consecutively on the two labels you wish to connect. To playback the concept mapping process, the playback button or the playback scrollbar is used. With the playback function, user can mark specific points in the concept mapping process. To mark the points, use the bookmarking function, then the bookmark (triangular mark) will appear above the playback scrollbar.

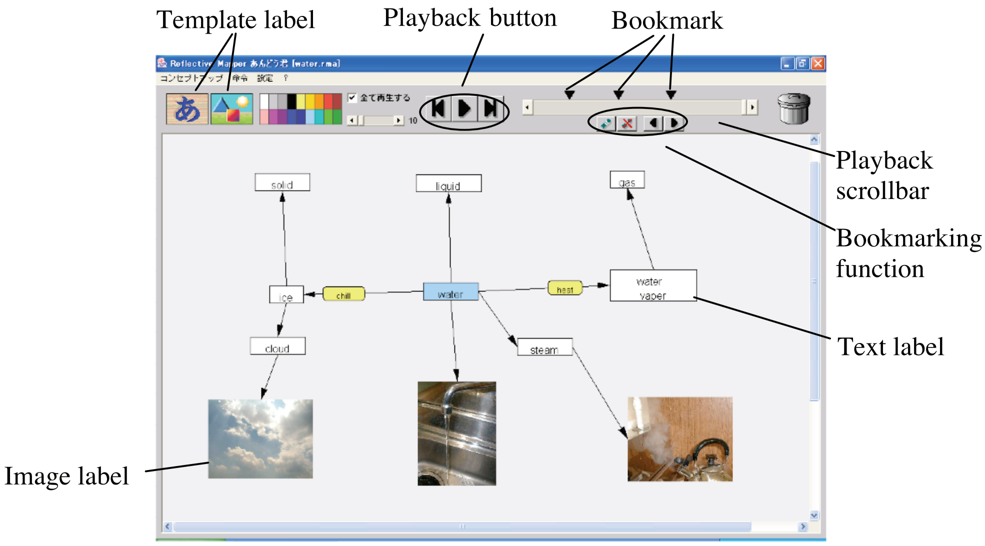

Figure 1. User interface of Concept Mapping Software for Reconstructing Learning Processes

3 Outline of the curriculum

The two lessons were conducted in a fourth-grade (ten years old) in a Japanese elementary school (lesson1: 34 students in 2004, lesson2: 35 students in 2006). The same unit “Three states of matter” (15 hours in total) were held in two lessons, and the purpose of the lesson was to understand that all kinds of matter have three different states, which are temperature-dependent. Throughout these lessons, each student created a concept map using the software. Table 1 shows the unit flow.

Figure 2 shows an example of the final scene of concept mapping by a student in lesson 1. The three states labels (solid, and liquid and gaseous) and ten substance labels(lead, wax, aluminum, naphthalene, salt, water, alcohol, carbon dioxide, oxygen, butane) were given to students. Students made links between state label to substance label if they think each substance change to each state.

Table 1. Unit flow

(1)	The teacher presents 10 materials (water, alcohol, aluminum, wax, lead, salt, naphthalene, butane, carbon dioxide and oxygen), and the students each predict whether these materials change their state (liquid, solid or gas) following temperature changes or not, and express their predictions by creating concept map using the software.
(2)	The class conducts experiments in which room-temperature liquid materials are cooled or heated, and the students correct their concept maps based on the results of the experiment.
(3)	Students reflect their concept-mapping process by using the software’s playback function and correct their predictions of the state changes of room-temperature solid and gaseous materials.
(4)	Students reflect on thinking processes by using the software’s playback function to look back on their concept mapping process and to explain their thinking processes others.
(5)	The class conducts experiments in which room-temperature solid materials are cooled or heated, and students correct their concept maps based on the results of the experiment.
(6)	Students reflect their concept-mapping processes by using the software’s playback function and correct their predictions of the state changes of room-temperature gaseous materials.
(7)	The class conducts an experiment in which room-temperature gaseous materials are cooled or heated, and students correct their concept maps based on the results of the experiment.
(8)	Students reflect their thinking processes by using the software’s playback function to look back on their concept mapping process and explain their thinking processes to others.

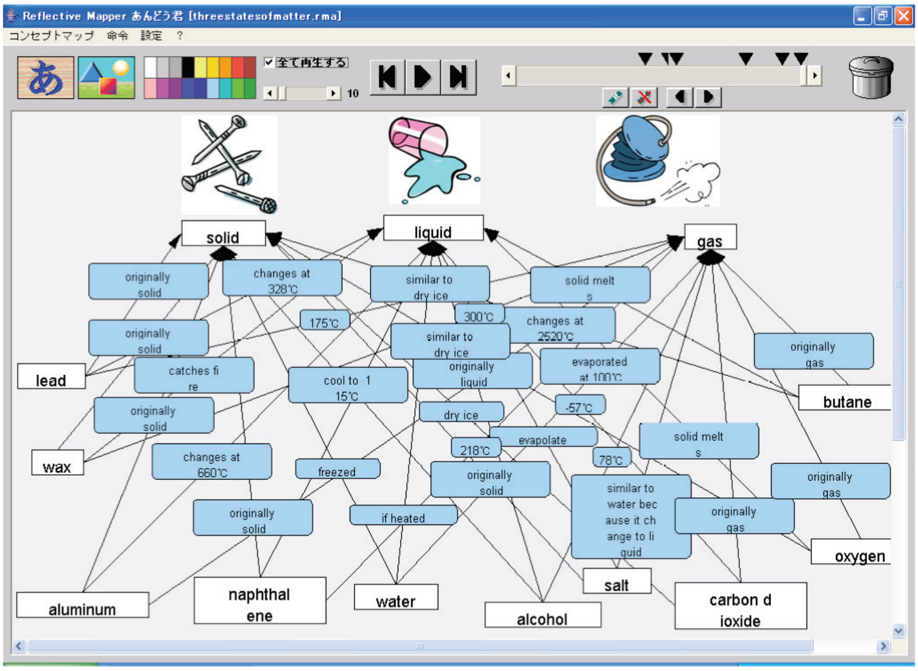

Figure 2. Example of a concept map created in the lesson 1

4 Improvement of the curriculum

Table 2 shows the curriculum improvement from the lesson in 2004 (lesson 1) to 2006 (lesson 2). The improved points were following three; form of concept map, manner of discussion, and focus on key factor.

4.1 Form of the concept map

In lesson 1, the form of concept map includes linking phrases between labels that represent detailed results of hands-on experiments that explained state changing of the substances (fig. 2). On the other hand, in lesson 2, we changed this form of concept map, not to make linking phrases and represent only links. One of the purposes of this lesson was to understand “every substances changes their states,” so we change the form of the concept map just to represent each substances “change” or “not change” their states by creating only links. Through this improvement of focusing students' simple idea of state changing on the concept map, we aimed to deepen students' scientific understanding of three states of matters.

4.2 Manner of discussion

When students have discussion (phase 4 and 8 in Table 1), in lesson 1, they explained their thinking process to others with no attention of common features or the different points between their concept maps. In lesson 2, we changed the manner of discussion to explain their thinking process with a focus on common features or the different points between their concept maps and to make intensive discussion about those features or points. We aimed to deepen students' scientific understanding of three states of matters through clarifying the viewpoints in explaining the thinking process, and focusing the discussion.

4.3 Focus on key factor

One of the key factors in this curriculum was the temperature, that substances change their states. In lesson 1, we didn't paid much attention on each temperature of state changing, but just showed the table of boiling and melting point at the end of the lesson. On the other hand, in lesson 2, we set the activity that students check boiling and melting point of the substances they treated after each three hands-on experiments (phase 2, 5 and 7 in Table 1). Setting this activity to confirm the boiling and melting point, we aimed that students reflect their own concept maps reconfirming the results of experiments which they changed the temperature of the substances. And furthermore, we aimed that students try to think “will other substances change their states if the temperature be changed?," that means, apply the concept of states changing of the substances represented on their concept maps to other substances they never treated in the lesson. Through such an experience, students' scientific understanding of three states of matter will be deepen.

Table 2. Improvement of the curriculum

	Lesson 1 (in 2004)	Lesson2 (in 2006)
Form of the concept map	With linking phrase	Without linking phrase
Manner of discussion	Without focus on common features or the different points	With focus on common features or the different points and make intensive discussion
Focus on key factor	Without focus on temperature that substances change their states	With focus on temperature that substances change their states

5 Comparative analysis of conceptual understanding

5.1 Method

5.1.1 Subjects

The subjects were the students joined the two lessons (lesson 1: 34 students, lesson 2: 35 students).

5.1.2 Tasks

Before and after the lesson regarding the three states of matter, each student had to take a pre-test and a post-test. Each test consisted of questions regarding 16 substances. Each question asked whether or not the substance existed in solid, liquid, and gaseous forms. In each question, students were given options: "exists," "does not exist," and "I have no idea." Before and after the lesson, students all together took a same test (pre-test and post-test). It took them approximately 15 minutes to answer the questions.

5.1.3 Analysis

Pre-test and post-test scores were obtained. One point was given to students who answered that every states of solid, liquid, and gas of a substance "exists." For nine substances learned in the unit, the perfect score was nine. For seven substances not learned in the unit, the perfect score was seven. For 16 substances in total, the perfect score was 16.

5.2 Results

Table 3 shows the results of the pre-test and post-test in lesson 1 and 2.

It shows the average score and standard deviation in the aspects of "all substances" "substances learned in the unit" and "substances not learned in the unit." In the aspect of "all substances," for example, students in lesson 1 had average pre-test and post-test score of 1.47 and 11.18, whereas in lesson 2 had 1.54 and 14.00. The average scores among the two lessons were compared using the one-factor analysis of variance between the subjects.

The result of the analysis of variance for the pre-test showed that in the aspects of "all substances" "substances learned in the unit" and "substances not learned in the unit," no significant differences in average scores were observed between the lessons ($F(1, 67)=0.20$ *n.s.* $F(1, 67)=0.60$ *n.s.* $F(1, 67)=0.02$ *n.s.*).

In the results of post-test, there was no significant difference in the aspect of "substances learned in the unit" between the lessons ($F(1, 67)=1.66$ *n.s.*). On the other hand, in the aspects of "all substances" and "substances not learned in the unit," there were significant differences in average scores between two lessons ($F(1, 67)=27.84$ $p<0.1$ $F(1, 67)=12.59$ $p<0.1$). It revealed that in the aspect of "all substances" and "substances not learned in the unit" in post-test, the average score of students in lesson 2 was significantly higher than that in lesson 1.

These results mean that in lesson 2 we improved the curriculum, the students were able to apply the knowledge about three states of matters to the substances that were not learned in the lesson, which could mean students' scientific understanding was deepen than in lesson 1.

Table 3. Results of the pre-test and post-test: average score (standard deviation)

Lesson	pre-test			post-test		
	all	learned	not learned	all	learned	not learned
Lesson 1	1.47	0.97	0.50	11.18	6.94	4.24
	(1.75)	(1.04)	(0.92)	(4.63)	(2.62)	(2.21)
Lesson 2	1.54	0.86	0.69	14.00	7.57	6.83
	(1.83)	(0.99)	(1.04)	(2.53)	(1.10)	(1.80)

N=34(lesson 1), 35(lesson 2).

6 Teacher's evaluation of improvement of the curriculum

6.1 Method

6.1.1 Subjects

The subject was an elementary school teacher who conducted lesson 2.

6.1.2 Tasks

A questionnaire based survey was conducted. The teacher answered the questions via e-mail. The teacher was told to freely answer the questions that ask whether three improvement points of the curriculum; form of concept map, manner of discussion, and focus on key factor were effective to deepen students' scientific understanding.

6.2 Results

The teacher evaluated that all of the three points to improve the curriculum were effective. Table 4 shows the results of the teachers' evaluation.

Regarding "form of concept map," he pointed that students could simply focus on the existence or nonexistence of the links by not representing linking phrase, when explaining their thinking and discussing the difference of their thinking. Furthermore, he also said that students could reflect their thinking process appropriately. From these results, this improvement was evaluated to be able to support students' discussion and reflection.

Regarding "manner of discussion," he evaluated that the activity of explaining their thinking process with a focus on common features or the different points and making intensive discussion about those features or points clarify the difference of their thinking, and focus the viewpoints of discussion. Furthermore, through recognizing the difference of their thinking, students could find the next issue. These results show that this improvement was evaluated to be able to support students' sharing of their thinking, and articulating the next issues to solve.

Regarding "focus on key factor," he evaluated that focusing on the boiling and melting point of the substances and confirming that state changing is related to the temperature could enhance the students' understanding of three states of matter. Furthermore, it was also evaluated that many students could apply the knowledge about three states of matters to the substances that were not learned in the lesson. From this result, this improvement was evaluated to be able to support students deepen their scientific understanding.

Table 4. Results of the teachers' evaluation

Aspects of improvements	Answer
Form of concept map	It was obvious when and how the links were added through playing back the concept mapping process. So students could reflect their thinking process appropriately. Without linking phrase, they could simply focus on with or without links, that means whether the substances change their states or not.
Manner of discussion	Students focus on the difference of their thinking each other. By focusing the point argument, they could intensively discuss why do they have different thinking, and deepen their understanding. For example, there was a student think that room-temperature gaseous substance change its state to liquid and solid, but another students think that change its states only to liquid. These situation made students recognize the next issue to solve.
Focus on key factor	After each three hands on experiments, I showed the table of boiling and melting point. I think, by confirming the temperature, students understand that substances change their states if they change the temperature. I think there are many students who could correctly apply the knowledge about three states of matters to the substances that were not learned in the lesson.

7 Conclusion

In this study, to make improvement of the elementary science curriculum using concept mapping software for reconstructing learning processes, we improved the lesson about three states of matter that was held in 2004 (lesson 1), and conducted a new lesson in 2006 (lesson 2).

We improved the curriculum based on three aspects, and conducted the comparative analysis of conceptual understanding, it was revealed that in lesson 2, students were able to apply the knowledge about three states of matters to the substances that were not learned in the lesson, which could mean students' scientific understanding was more deepen than in lesson 1. Furthermore, it was showed that the teacher who conducted lesson 2 evaluated that all of the three aspect of improvement were effective to support students deepen their understanding of three states of matter.

Following two points will be mentioned as future tasks. Firstly, more detailed comparison between two lessons has to be conducted. And secondly, design principle of the lesson in introducing concept mapping software into school lesson have to be more examined through accumulating consecutive research.

8 Acknowledgements

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A DEVELOPMENTAL FRAMEWORK FOR ASSESSING CONCEPT MAPS

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Abstract: This paper describes the application of a developmental assessment model to the analysis of concept maps prepared by students in upper primary, mid-secondary and senior years of schooling. The model, referred to as SOLO (Structure of the Observed Learning Outcome), provides a means for interpreting student responses within a framework of cognitive growth. A key feature of the model is its focus on the quality of a student response. Based on a discussion of key features of students' concept maps, descriptors are proposed from a SOLO perspective for increasingly complex concept maps.

1 Introduction

The qualitative analysis of concept maps has focused on detailed descriptions of map features. Such descriptions have documented similarities and differences in the way groups of students manipulate concepts (Williams, 1995), the extent to which maps exhibit progressive differentiation (Henderson, Patching, & Putt, 1994; Starr & Krajcik, 1990) and when changes take place in student's conceptual understanding over time (Fellows, 1993). In addition to the misconceptions and inconsistencies which concept maps reveal, they can also be analyzed for the gaps that are apparent in students' knowledge. Such gaps may not only be representative of missing concepts, they may also suggest that conceptual relationships have not yet been made between items in a student's cognitive structure. Fellows (1993) used a number of criteria to analyze concept map changes over time. These criteria included the incorporation of new concepts, the addition of domains of knowledge, the hierarchical organization of concepts, and the identification of strongly held beliefs. There have also been suggestions that analysing the diversity and richness of concept maps would benefit from a " ... holistic and qualitative technique" (Stuart, 1985) or that "as students develop increasingly sophisticated scientific knowledge, it might be useful to distinguish their statements via a more elaborate hierarchy of accuracy ... " (Stoddart, Abrams, Gasper, & Canaday, 2000). The guiding question for this paper is whether or not descriptors for distinctly different groups of concept maps can be developed from the perspective of a cognitive structural model that places student responses within cycles of growth of increasing complexity. Such a focus has the potential to supplement investigations that have focused on the structural changes that can be observed in concept maps over time.

2 The SOLO Model

The SOLO model is a post-Piagetian analytical tool that has the potential to distinguish qualitatively different levels of response to a task along a developmental continuum. The SOLO classification scheme refers to the Structure of the Observed Learning Outcome (Biggs & Collis, 1982). Coding a response – rather than a student, according to the SOLO model requires a consideration, firstly, of the nature of the elements that are used and the complexity of the operations that can be applied to those elements. Such a consideration gives rise, firstly, to *modes* of thinking that are related to the abstractness of thinking. There are five main modes of cognitive functioning within the SOLO model and these are currently referred to as (1) sensorimotor – acquiring motor skills; (2) ikonic – thinking intuitively; (3) concrete symbolic – representing concepts using different symbol systems; (4) formal; and (5) post-formal – manipulating theoretical constructs. Secondly, as an individual becomes more and more familiar with the elements and operations within a mode, a pattern of response structure becomes apparent according to the ease with which students process cues, something which may be related to working memory.

In general, most primary and secondary school students interpret phenomena or undertake tasks within the concrete symbolic mode. This mode is the prime focus for the compulsory school years. As a consequence, during these school years, concrete symbolic is referred to as the target mode (Biggs & Collis, 1989). The goal in any target mode is to raise the level of functioning to the point where responses can be made at a level of sophistication that indicates that the quality of learning which has taken place is adequate or that a skill has been practised sufficiently (Collis & Biggs, 1991). A consideration of increasing complexity gives rise to the second feature of the model, namely *levels* of responses. There are five main levels of responding within the model: *Prestructural* (P) – no use of elements which belong to the mode in question; *Unistructural* (U) – identification of one relevant element of the required mode; *Multistructural* (M) – thinking about two or more pieces of information relevant to the target mode; *Relational* (R) – the relationships between separate pieces of information have been considered to produce an integrated understanding; *Extended Abstract* (EA) – a transition to a new mode of thinking through the use of material which is new or of increased abstraction.

Of the five SOLO levels, three constitute a learning cycle within a particular mode, namely, unistructural, multistructural and relational, whilst the other two, pre-structural and extended abstract, lie outside this mode (Biggs & Collis, 1982, 1989). Entry into a mode is determined by a unistructural response in that mode of functioning or by moving beyond the relational level in a previous mode. Transcending the relational level implies the ability to formulate an extended abstract response and the overlap between an extended abstract response in one mode and a unistructural response in the next mode is explained as "the extended abstract response in one mode jumps the barrier to form the unistructural response for the next higher mode" (Biggs & Collis, 1982, p.218). The model proposed (Biggs & Collis, 1991) brings together successively the cyclical nature of learning (levels) and the hierarchical nature of cognitive development (modes). Inherent in the learning cycle is a sequence from low competence (novice learner) to expertise (Biggs & Collis, 1989) with each level being an indicator of how far learning has progressed towards competence. The sequential progression through the learning cycle, with progression towards modes of higher abstraction in an 'onwards and ever upwards' process has been termed the course of optimal (cognitive) development (Biggs & Collis, 1989). In later developments of the SOLO model, the notion of the course of optimal development has undergone refinements to incorporate linear development within a mode and development across modes (Collis, 1988; Biggs & Collis, 1989). The terms 'unimodal' and 'multimodal' are introduced to explain expertise and intelligent behaviour (Biggs & Collis, 1991). In addition, the notion of the U-M-R learning cycle has been refined to incorporate multiple cycles within a mode (e.g., Collis, Jones, Watson, Sprod & Fraser, 1998; Panizzon, 1997; Pegg, 2003).

3 Data – 'Matter' Concept Maps

Ten maps are briefly discussed in terms of the holistic arrangement of concepts and the meaning developed based on proposition grouping and the linking of concepts. The maps were prepared collaboratively by students in groups of 3-4 from Year 4/5 (upper primary), Year 9 (middle secondary) and Year 11 (senior secondary) using 20 words about 'matter'. The students were from an all girls' boarding school in a regional location. They were not experienced in concept mapping and a series of four 1-hour structured sessions provided them with practice in acquiring the necessary techniques. Throughout the discussion that follows, reference is made to 'themes' in an 'expert' concept map. The 'expert' was a post-graduate student with a background in the physical sciences and some familiarity with concept mapping. The 'themes' refer to the way concepts were grouped using the same words provided to the students and they were identified as: the classification of matter; changes of state; kinetic-molecular behaviour of particles; an atomic description of matter.

Map 1: The way each of the concepts is placed separately around the main concept in Figure 1 provides an example of a structurally *Discrete* map – one of six visual descriptions of maps. Single words have been selected from each of the four 'expert' map themes, however, these themes are not developed.

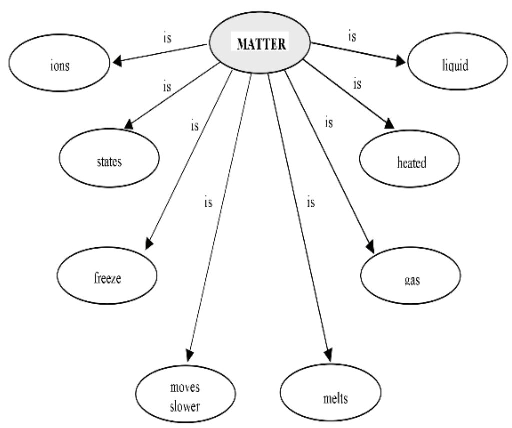


Figure 1 Concept Map of 'Matter' for Group Yr4/5 B1

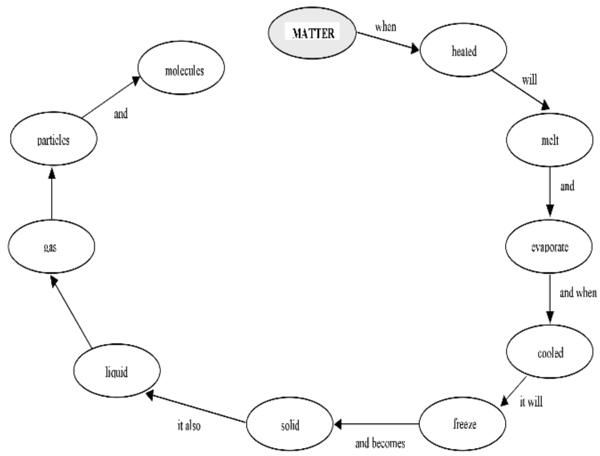


Figure 2 Concept Map of 'Matter' for Group Yr4/5 A2

The main feature of this map is the presentation of discrete pieces of information, ordered as single propositions incorporating the same link term throughout. The construction of a generalizable proposition (one that is part of an agreed shared language within a discipline, such as science) is almost coincidental, suggesting that students have focused more on the correct appearance of a proposition than on the propositions themselves. In SOLO terms, this suggests an Ikonic mode of thinking.

Map2: This is an example of a *Single Strand* map (Figure 2) and it incorporates three of the themes identified in the 'expert' map. The main focus is on changes of state and the six concepts which begin this strand are used to list propositions about the behaviour of matter when it is heated or cooled, i.e., it will melt, evaporate, and freeze. Although there is a break in the 'flow' of ideas after the concept 'solid,' the listing of attributes of matter is maintained, with four additional concepts added as labels for matter. These concepts concern the classification and the atomic nature of matter, and it is of interest that the students who prepared this map have extended one strand rather than begin the process of constructing another strand based on a different theme. In SOLO terms this map is consistent with a multistructural level of treating concepts.

Map 3: This is an example of a *Multiple Strand – linear* map (Figure 3). Based on 9 of the 20 terms provided, one strand describes changes of state whilst the second strand makes reference to an atomic view of matter. The separation of this information into two thematic strands suggests that students may have made decisions about the underlying meaning of each strand. Whilst students may have been able to use the map structure to distinguish between different themes, the main feature of this map is the sequential presentation of information. One theme is stated and then students have begun again to present new information. In SOLO terms, such a treatment is consistent with a multistructural level.

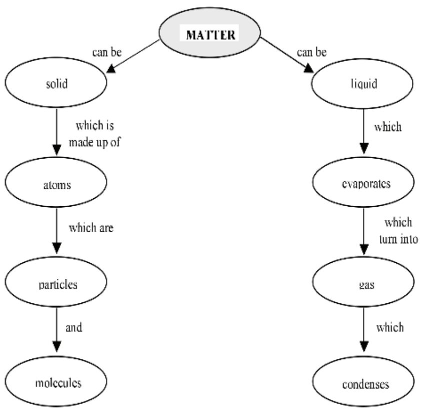


Figure 3 Concept Map of 'Matter' for Group Yr4/5 C2

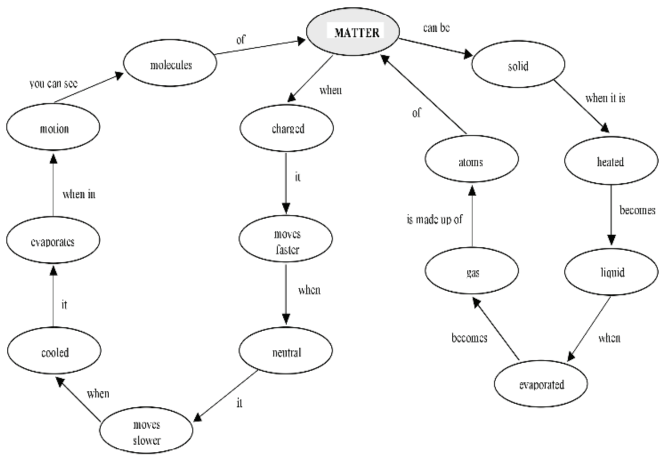


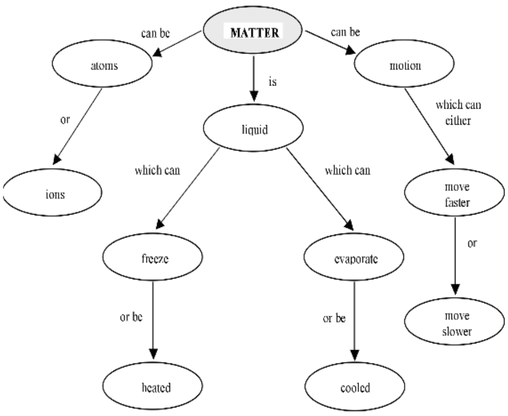
Figure 4 Concept Map of 'Matter' for Group Yr4/5 B1

In the right hand strand, students indicated that they could recognize changes of state that involve heating and cooling, applying this to liquids and gases, respectively. Even though 'solid' was included in the map, it has not been incorporated into the changes of state theme. There are two possible explanations for the absence of this link. One is that students cannot use a concept in multiple contexts: students may not have recognized that 'solid' has a meaning within a changes of state theme *and* an atomic view of matter theme. Secondly, the physical (visual) separation of a concept has possibly prevented students identifying a conceptual link. As with Map 1, the complexity of this map may be related to the number of elements that students can consider concurrently, namely, creating propositions and using the structural components of a concept map.

Map 4: The arrangement of concepts in this map (Figure 4) provides another example of a *Multiple Strand – linear* map with words grouped according to all four 'expert' map themes. The sequencing of these words, however, is different from the previous example. Here, they take the form of separate groups of propositions. The 'flow' of the left hand strand of this map is not continuous as it can be written out as four statements, each of which is about a different aspect of matter. This strand does not therefore convey understanding about a single theme. Rather, it represents the listing of different aspects of matter. The first of the statements uses the concept 'charged' in an everyday context, as has 'neutral' in the next proposition. The next statement, on initial inspection, indicates a faulty proposition. This reference to evaporation, however, could represent the recollection of observations made about the appearance of frozen objects when removed from a freezer. As a consequence, the underlying meaning of this statement is not immediately apparent and it imparts a context-specific nature or personally relevant meaning to the strand.

The second strand in this map can also be written as a number of separate statements, the main focus of which is changes of state. This theme is conveyed using six concepts in a continuous way and there is no need to repeat the main concept in order to make a proposition meaningful. After this sequence of propositions, a different theme is introduced, that of atoms. The meaning conveyed by both groups of propositions is generalizable. In SOLO terms, the way students have been able to maintain the 'flow' of concepts is consistent with a relational level of thinking. This map reflects another aspect of applying the model, namely that a level is assigned to a response on the basis of its most complex feature. This map reflects both individual and scientific perspectives, with the later taken as the more complex.

Map 5: This is an example of a *Multiple Strand - branched* map (Figure 5), a structure that has been used to group concepts related to each of the four 'expert' map themes. In common with the previous example, the strands are short and a separate one is used for each theme.



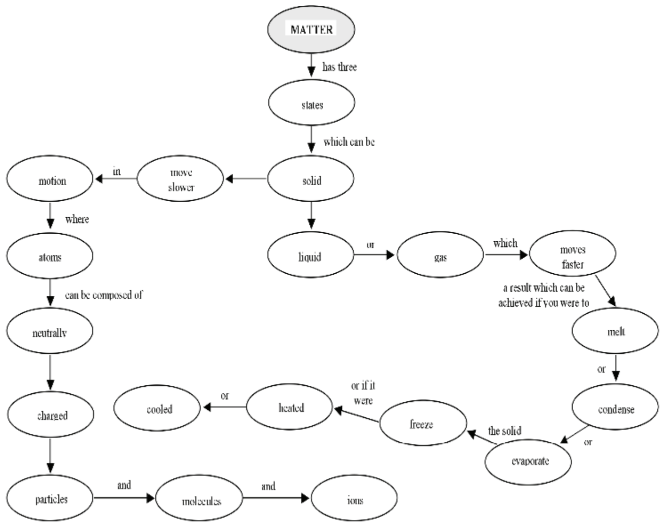


Figure 5 Concept Map of 'Matter' for Group Yr4/5 E2

Figure 6 Concept Map of 'Matter' for Group Yr9 A2

The first linear strand makes a generalizable statement about the atomic description of matter based on the recall of discrete pieces of information. The other linear strand refers to the behaviour of matter with some indication that it is based more on everyday observations than on abstract concepts. The focus on either particles or motion is consistent with a unistructural level of thinking. The main point of interest in this map is the way in which concepts relating to states and changes of state have been treated. One state has been selected and this has become a branching point for a discussion of changes of state. In this sense, the strands comprise two themes, however, they have been linked without any interruption to the 'flow' of meaning. The focus of these strands is that a liquid can undergo two changes, one associated with heating and the other with cooling. It is interesting to note that the terms 'heated' and 'cooled' are associated with terms of opposite meaning, e.g., " ... liquid which can freeze or be heated." Such a sequence indicates an understanding of the two-way processes that apply to a liquid and this conveys a preliminary awareness of the notion of reversible processes. The main feature of this map is the use of strands to link propositions in two qualitatively different ways that can be explained in terms of qualification. The first relates to the use of a link word, such as "or", that leads to the construction of a strand in which information is itemized, i.e., without qualification. The second relates to links, such as "which can", that allow for propositions to be qualified. The qualified propositions can convey a more detailed understanding of concepts. Such qualification of one concept is consistent with unistructural thinking at a complex level.

Map 6: This is an example of a *Single Strand – branched* map (Figure 6), even though the major part of this map comprises two strands. All the terms provided were used in the map and, consequently, the potential exists for all four themes of the 'expert' map to be discussed. With only two strands, however, there are implications for how students treat the 'flow' of ideas along these strands. The first theme to be stated is that of classification into states and a branching point introduces the idea of the motion of particles. The motion theme becomes the cue, and provides a transition to a discussion about matter from the atomic viewpoint. The ideas about motion and the atomic view of matter are not integrated and this lack of integration generates a break in the 'flow' of meaning. In the right hand strand, the motion theme again provides a transition to ideas about changes of state. With the terms 'moves faster' and 'melt', students have attempted to make a causal connection between motion and the processes associated with changes of state. The intent to maintain ‘flow’ along this strand is reinforced through the repetition of the term ‘solid’ later in the strand. The lengthy strand structure, however, has not resulted in a clear enough distinction between terms associated with changes of state and, consequently, the integration of ideas about heating and cooling contained in this strand does not have continuous ‘flow’. This confusion might have been resolved with the inclusion of a branching point, however, students appeared unable to incorporate this feature into their thinking about matter. A key feature of this map is that the separate strands are representative of the sequencing of a number of themes with breaks in the ‘flow’ of meaning. In SOLO terms, these breaks in the ‘flow’ reflect a multistructural level of thinking. Overall, however, this map is consistent with unistructural thinking at a complex level in the way one aspect (e.g., motion) of a theme (e.g., changes of state) is developed.

Map 7: This is an example of a *Multiple Strand - branched* map (Figure 7) which uses terms associated with each of the four ‘expert’ map themes. The two outer strands focus on states and changes of state and the two inner strands focus on kinetic-molecular and atomic aspects of matter. The two strands which outline changes of state detail the macroscopic, observable, features of this change. The shorter of the two strands comprises a simple, generalizable, statement that matter “melts then evaporates,” processes which require heat. In contrast, the second strand specifies each state and the processes which form the sequence of the cooling of a gas, even though heat is not explicitly mentioned. Considered together, these two strands convey the notion of reversibility, although the absence of links between them in this map results in this idea remaining implicit.

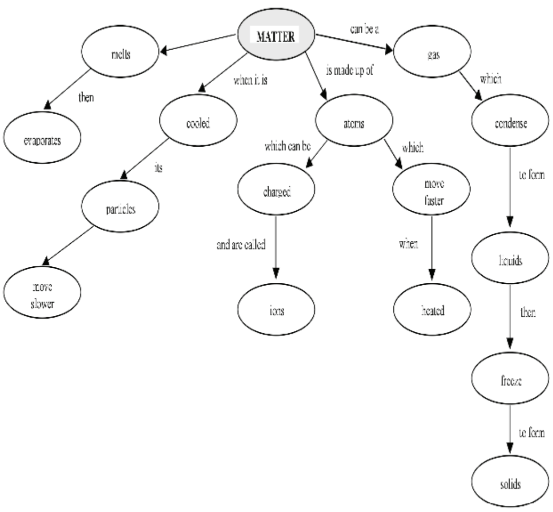


Figure 7 Concept Map of ‘Matter’ for Group Yr9 B2

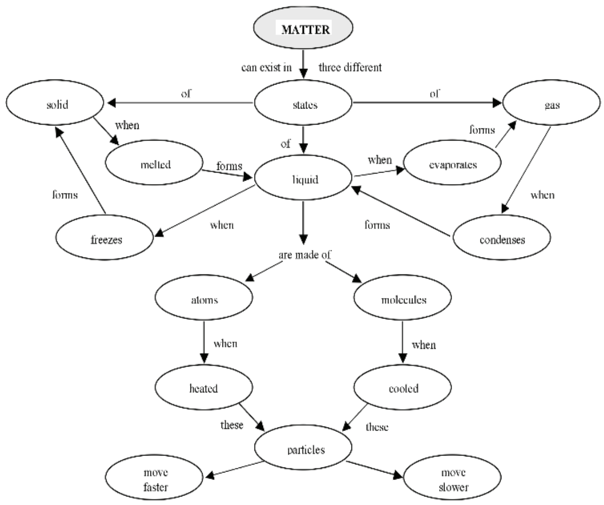


Figure 8 Concept Map of ‘Matter’ for Group Yr9 F1

The two central strands follow a similar pattern. The left-hand strand represents a generalizable statement about the behaviour of cooled particles. The second strand also integrates two themes. The way this is achieved, however, is different from the strand about states and changes of state. In this strand, the term ‘atom’ has become a cue for students to discuss two separate ideas about atoms, namely their particle nature and motion. One meaning relates to an atomic view of matter and the other to a kinetic-molecular context. The main feature of this map is the way in which the structural features of maps have been used to integrate themes along a strand. The potential existed within this map for a cross-link to be made, however, this structural feature was not incorporated and this may reflect the limit of students’ processing as they managed the requirements of the task and their understandings. In SOLO terms, the capacity to present a theme (e.g., the motion of particles) and elaborate on one aspect (e.g., the charged nature of particles) is consistent with unistructural thinking at a complex level.

Map 8: This is an example of a *Complex* map (Figure 8), indicating that all of the structural features of maps have been included. In addition, terms have been selected which are associated with the four themes of the ‘expert’ map. In the first section of this map, the concept ‘states’ is used as a branching point to identify the three states of matter. Propositions are then added which, together, give an overview of all of the processes that are associated with changes of state. In addition, these propositions are cross-linked in a way which conveys the notion of reversibility. In the sequence of propositions “a solid when melted forms a liquid when freezes forms a solid,” for example, both the heating and the cooling processes are itemized. This arrangement can be compared with the map in Figure 7 where the ideas are arranged separately. In the second section of the map, the concept ‘solid’ becomes the cue for integrating ideas about the kinetic molecular and particle aspects of matter. The main feature of this map is the use of all mapping structural features to integrate themes in a generalizable way without a loss in the ‘flow’ of meaning. In addition, the notion of reversibility, which is not an explicit part of the words provided, is conveyed through the use of two-way cross-links. The features in this map make it consistent with relational thinking at a complex level.

Map 9: This has been classified as *Multiple Strand - branched* (Figure 9) and all the themes of the ‘expert’ map have been included. Additional words have been added to extend the information about the atomic view and, unlike other maps, a number of the provided words are repeated with most of the repetition occurring in the section about states and changes of state. All of the changes of state are itemized and discussed in terms of the effects of heating and cooling. The underlying structure used to convey this information, however, is a one-directional ‘flow’ along a strand. As has been noted in other examples, the notion of reversibility is implicit and, because students do not appear to have a facility with cross-links, this additional theme remains unstated. The proposition “ ... solid is heated to become liquid ” is the only appearance of a cross-link.

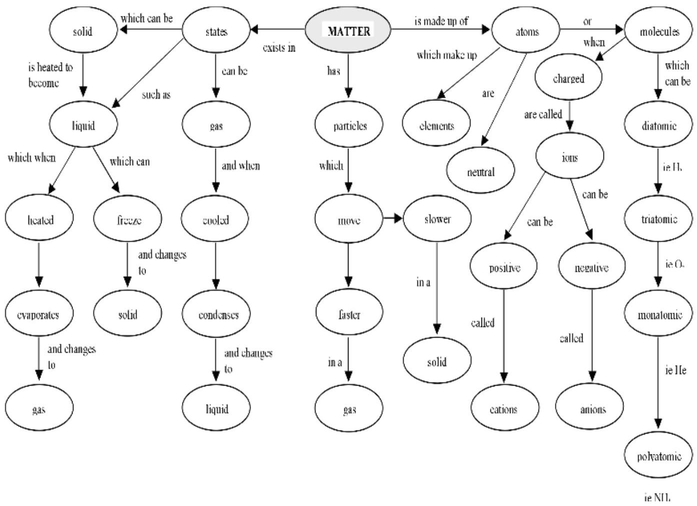


Figure 9 Concept Map of ‘Matter’ for Group Yr11 B1

In the middle section of the map, the motion of particles is considered as a function of their state, an approach that distinguishes this map from others in which the effects of heat were outlined. Finally, the atomic picture of matter is put forward in the last section of this map inclusive of references to the charged nature of atoms and molecules. Although implicit, a distinction between atoms and molecules is made by the inclusion of terms such as ‘diatomic’ and ‘formulae,’ suggesting that students are familiar with the notion of combining atoms. The main features of this map are its extended concept base and the extensive use of strands to itemize information. The elaboration of a number of themes is consistent with multistructural thinking at a complex level.

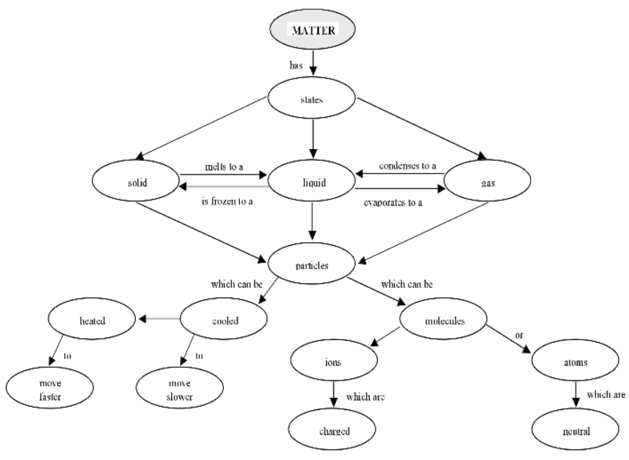


Figure 10 Concept Map of ‘Matter’ for Group Yr11 A1

Map 10: This is an example of a *Complex* map (Figure 10) based on terms associated with each of the four themes of the ‘expert’ map. Both structurally, and in the way ideas are developed, there are similarities between this map and the Year 9 map Yr9F1 (Figure 8). The underlying structure is the use of strands to integrate themes with no interruption to the 'flow' of meaning. In addition, cross-links are used to detail the reversible processes associated with changes of state. Statements are made about the behaviour of particles when heated or cooled, and the concept 'particle' has been used as a focal point for making a distinction between kinetic and atomic aspects of matter. The features in this map make it consistent with relational thinking at a complex level.

4 Concept Maps – A SOLO Perspective

The maps presented in the previous section illustrate some distinctive features of concept maps that can be summarised under three headings. The first relates to the holistic (visual) arrangement of concepts and there was sufficient variation to identify six distinctly different types of maps based on the way structural elements of maps were used. These types were labelled *Discrete*, *Single Strand*, *Single Strand – Branched*, *Multiple Strand*, *Multiple Strand – Branched*, and *Complex*. The second feature of the maps relates to the grouping of propositions. Again, sufficient variation existed to identify maps that ranged from single propositions only through to those that comprised cross-linked strands where the individual strands were made up of sequential 'themes'. For example, the strand was the main structural feature used by Year 4/5 students whilst branching points became an important feature of Year 9 maps, and the inclusion of cross-links characterized Year 11 maps. The third feature of the maps is linked to the way groups of propositions generate meaning. Some key terms used to describe groupings were *itemising* – individual pieces of information listed, *integrating* – links between ideas or themes were identified, *'flow'* – which could be broken or continuous, *personally relevant* – where propositions generated a non-scientific context, and *generalizable* – where the meaning was developed as part of the shared language of the discipline of science. These three features provide a basis for using the SOLO model to formulate descriptions of structural categories for distinctly different maps. These categories are based on the number of elements chosen and how students work with those elements. Applying the descriptors proposed below, most of the maps could be assigned to the Concrete Symbolic mode – the target mode for instruction. Although these examples reflect an age-related progression towards structural complexity, it is important to realise that the structural features of the map are important not who created it. Whilst not all concept maps will necessarily fit a descriptor exactly, each level will have certain essential features that enable a map to be placed within a developmental sequence.

- **Ikonic**: There is a perceptual focus in this mode and there is a sense that students are concentrating on what a concept map should look like (visual correctness) rather than using propositions to create meaning. Propositions are poorly constructed, propositional links may be absent, or a personally relevant context might be conveyed (e.g., *Map 1*).
- **Concrete Symbolic**: This is the mode of building (first cycle) and working with (second cycle) conceptual understandings as part of a scientific framework. Within the first cycle, concepts may be treated in a personally relevant way alongside the emergence of scientific understandings. Within the second cycle, students are able to work with propositions in a science-based context and demonstrate a more complex level of thinking.
- **U_{1CS}**: A few independent concepts related to the main concept are listed as a single strand or as a number of short strands. If linked, there is a repetition, or implied repetition, of the main concept. (e.g., *the outer strands of Map 5*).
- **M_{1CS}**: A number of concepts are linked without the need to repeat the main concept. More than one idea about the main concept is contained in the strand indicating that students are able to think about a number of aspects of one theme related to the main concept at the same time. These ideas are expressed independently, in a list-like way (e.g., *Maps 2 and 3*).
- **R_{1CS}**: A feature of the main concept is developed using linked ideas. This development can be equivalent to a story is being told indicating that students have seen the links between separate propositions. There may be some initial attempts at branching, however, these are not fully developed ideas (e.g., *the right hand strand of Map 4*).
- **U_{2CS}**: A number of strands comprising linked ideas are used to describe a feature of the main concept. Students are able to identify a feature by linking concepts and can elaborate on one aspect of that feature. Branching is used once to elaborate the particular term or idea (e.g., *Maps 5, 6 &7).*
- **M_{2CS}**: More than one meaningful branching point is used to develop features of the main concept. Links are identified between these features although responses still maintain a direction of 'flow' of ideas that is in one direction from the main concept (e.g., *Map 9*).
- **R_{2CS}**: Development of features of the main concept extends to the inclusion of reversible links. The framework of concepts is constructed so that the 'flow' of ideas can occur in two directions (e.g., *Maps 8 &10*).

5 Conclusion

The structural underpinnings of the SOLO model provided a potentially informing framework from which to interpret variations in structural complexity of concept maps. Descriptors for modes and levels have been proposed that place increasingly complex maps within a developmental sequence. The identification of two cycles within the concrete symbolic mode reinforces findings for a number of mathematics and science concepts where studies have detailed the characteristics of the cycles as students move from the perceptual focus of the ikonic mode through the construction of concrete concepts (first cycle) and their application in reality bound problems (second cycle). The analysis of concept maps in this study has implications for applications of the model and for providing additional information about cycle characteristics. In addition, responses coded within the first cycle of the concrete symbolic mode were characterized by the use of ikonic imagery as a reference point for the construction of science concepts. The observation of such ikonic support, or multimodal functioning, is also consistent with studies reported in the literature. Whilst the SOLO model can be used as an assessment framework for concept maps based on visual appearance and propositional groupings, further investigations are needed in order to continue to refine descriptive categories for modes and levels, and to investigate further parallels between the structure of the model and the structure of maps. Such investigations would need to be based on maps prepared by students across a broad age range and for a range of curriculum areas. This study has hinted at benefits for both the SOLO model and for concept maps. Continued application of the model has the potential to chart map constructs, such as progressive differentiation, and the qualitative changes that are evident in student learning over time. Continued analyses of concept maps also have the potential to provide important information for the model concerning the way students work with concepts during important level transitions.

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A FRAMEWORK TO HELP CONSTRUCTING DISTANCE LEARNING ACTIVITIES ON CONCEPT MAPPING FOR EDUCATION

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Abstract. This work presents the first results on developing a distance learning intervention methodology designed to potentialize a collective learning environment set up by an educational portal addressed to the use of concept maps on a piagetian constructivist approach. The results consist on a set of orientations in order to construct the activities for distance learning courses as well as suggestions on teaching procedures (interventions) on those courses. **Keywords:** distance learning, concept maps, continued learning and intervention methodology.

1 Presentation

The investigation on psychological and epistemological foundations for the use of concept maps in educational activities is one of the main focuses of the Laboratory of Distance Learning Studies (Le@d.CAp), a UFRGS research group. The researches produced results such as the elaboration of analysis models and methods of concept maps supported by Jean Piaget's Genetic Epistemology and Jean-Blaise Grize's Natural Logic (Dutra, Fagundes & Cañas, 2004). Such concept map approach, innovative in relation to the classic theories which support this type of knowledge representation, resulted in the production of a set of analysis criteria of conceptualization processes using a temporal sequence of Concept Maps from the same individual, on the same subject (Dutra, 2006).

To make it well known and to improve its scientific production, the Le@dCAp research group, through Concept Map in Education portal (MCE site) has been offering experiences in working with webs since 2003, built according to models that privilege more deepened education practice discussions, focusing on concept learning. Professionals and students, who are interested in using the concept maps for learning development and evaluation, find in the MCE portal a space for discussion and sharing of ideas which privilege the interaction among the participants as a way to provide learning.

Consequently, the distance courses, offered to the communities of the MCE portal participants, become a unique space to test and to obtain data, which will verify the efficiency in different contexts of the models produced in the Le@dCAp. For this reason, we consider extremely important the analyses of the results obtained in such courses in order to identify and to systematize, in method, the set of factors which were capable of producing efficient interventions using the interaction elements in each case. The support offered by virtual interaction tools like chats, forums, e-mail lists and blogs, provides the record of activities performed and the interactions promoted, therefore, allowing their analysis and classification.

Following, we will present a brief contextualization of the theoretical tool and the actions conducted through the MCE portal to show the results and considerations obtained from the analysis of materials and orientations available for each course, as well as the students' and teachers' participation records.

2 The concept maps, MCE portal and the courses analyzed

The MCE portal has a series of functions which allow its participants to contribute, to learn and to interact autonomously through co- authored activities. As soon as each participant is registered in the portal, his/her electronic address is automatically included in the attached Discussion list through the e-mail address mapasconceituais@grupos.ufrgs.br , a fast and reliable way to raise and to raise discussions is available for them, as well as to report work, events and other actions related to the use of Concept Maps.

It is also possible for the participants to have access to the required resources to register an activity through an Environment for Activity Creation and Edition (AÇAI), therefore to form a community which can include other listed participants. This file creates a virtual space similar to a blog where objectives, aims, strategies and evaluation criteria can be seen, and also the motivation of the people in charge. Moreover, the responsible ones can write in a Daily Record where the activities can be described, the files annexed, digital images sent, and related links listed. Other participants (listed or not in the portal) can interact with the activity, sending comments to the diaries or to the whole community.

In addition to these ways of interaction among the portal participants in the Forums, it is possible to create some discussions on specific questions asked by the community. Every participant can create a discussion forum as well as to be involved in the discussions proposed by the colleagues. The Forum messages are organized hierarchically with information about the one who wrote it and when it was posted. Search tools allow highlighting the messages according to the postage date criteria and keywords.

In the space denominated Productions, materials produced by the community which uses the Concept Map in Education can be found. Any registered participant can send materials according to the categories indicated. With a search tool, the user can specify the material he is looking for including articles, texts, presentations, even concept maps.

3 Method

The courses offered by MCE Portal and analyzed for this study were developed according to the following strategies:

- Short duration courses (around 3 to 4 weeks with 60 maximum working hours); in all of them, there was a discussion list support of the portal to send orientations and to solve any doubts related to the elements used for the activities;
- Two of the courses analyzed were completely performed with the available blog in the portal: the orientations were posted as a daily record in addition to the students' productions (the image files generated by the concept maps were annexed to each diary), and the interactions and interventions were carried out through the diary Comments;
- The other two courses used the software CmapTools (Cañas et al, 1994, 2004) and a concept map server (CmapServer) which allow sharing via internet the maps as well as the possibilities to provide a Discussion Thread (online discussion forums which can be annexed to the concepts or links of a map produced in the CmapTools and saved in the map server);
- In one of them, a videoconference was made through the Macromedia Breeze available in the UFRGS server: in addition to the audio and video broadcasts (bidirectional), it was possible to share documents (PowerPoint presentations, pictures, etc.) and to interact via chat.

The method involved the activity analyses and the orientations for its use, as well as the interventions made by the teachers in contrast with the participants' course productions to obtain the leading principles of the activity production and the interventions made (not only by the teachers but also by the participants' interaction). For this reason, intervention means, for this study context, each proposal activity and the interactions in which teacher ↔ student or for those that involve student ↔ student.

4 Results

The work method for the development of the course activities consists of allowing exchanges supported by the available texts and materials in this environment among the participants. Consequently, the records produced for these interactions become the main learning evidence of each one of them. Considering this, frequency and participation evaluation are linked to the participation quantity and quality which are effectively registered in the environment, that is, the postage of messages requested in each activity, the participation in the synchronous interactions and to the sending of material (in general, concept maps transformed in figures).

The initial design of each course offered by the MCE portal follows a set of principles which were systematized in the concept map of Figure 1 as the following:

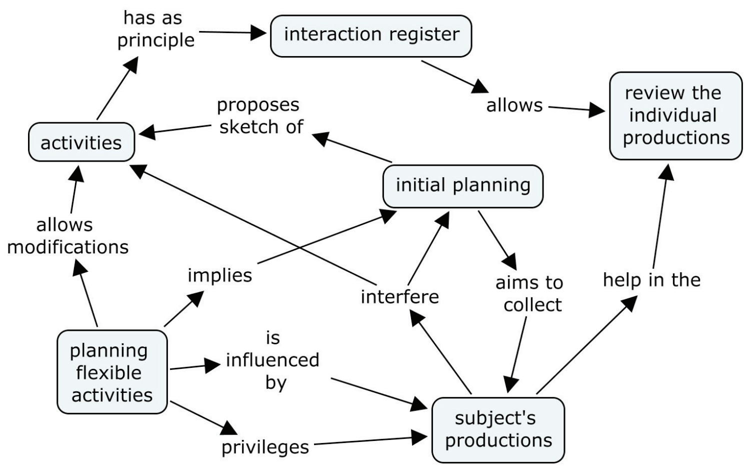

Figure 1. Principles which rule the planning of the course activities in the MCE Portal

Let's consider as an example, the following sequence of activities produced for the Constructivist Approach Course of Concept Maps (2007):

- The first activity consisted in the elaboration of a concept map (using the CmapTools software) that would represent each one's understanding in respect to the differences among the approaches proposed by the meaningful learning and the genetic epistemology. To do so, two texts were offered: concept maps and meaning learning and concept maps and genetic epistemology. In addition, the elaboration of a text was requested to explain the map built, clarifying and discussing their propositions. The text and the figure of the concept map were posted on the blog individually.
- In the second activity, we asked each participant to interview two classmates from their group regarding the maps and texts produced by both. This interview was performed in the comment section of each Diary to obtain the classmates' point of view about their productions.
- Finally, after the round of messages and the videoconference, each participant had to produce a second version of the concept map built in the first activity as well as of the explicative text related to it. An evaluation related to the learning (self-evaluation) as well as the methodology applied in the course including suggestions of possible themes for new courses.

In this activity description, some highlighted aspects in the concept map in figure 1 are presented The first activity , although simple, aimed at obtaining records from the participants in the form of concept maps, which could explicit not only their comprehension of the theoretic aspects involved in the texts but also their ability to construct a concept map. The complement regarding this first action by the students, that is, a request for the explanatory text resulted in observing the previous activities in which the intervention by the teachers as well as the course participants in general did not involve the totality of the concept maps and the relationship systems represented in each map.

The second activity can be considered the main focus of the sequence shown. The questions and answers obtained in each interview turn could be contrasted by each diary board. That is, sometimes, the explanation that each participant asked his classmates was already present in the diary containing the map. At times, the participant himself would realize that his explanation or his map could be complemented or was not clear enough, considering the question or suggestion given by his classmate. As everything was registered and could be reviewed as many times as necessary, so the exchange sequence allowed the review proposition of the first production of each student (the concept map) in the third activity.

Thus, in relation to the activity propositions as an intervention method, the principles described previously (in the concept map, figure 2) regulate the production systematic of the course material in order to establish, once the course contents were defined, the performance strategies of teachers and participants. Therefore, we can state that a flexible activity plan that privileges the production analyses of the course participants will help in the intervention (by the teachers and the students).

In the second example, there is a sequence of Concept Maps extracts produced by a course participant "Concept Maps in Learning Evaluation" (2005) and among them, the interventions made by the teacher and other participants in order to modify (improve) such production.

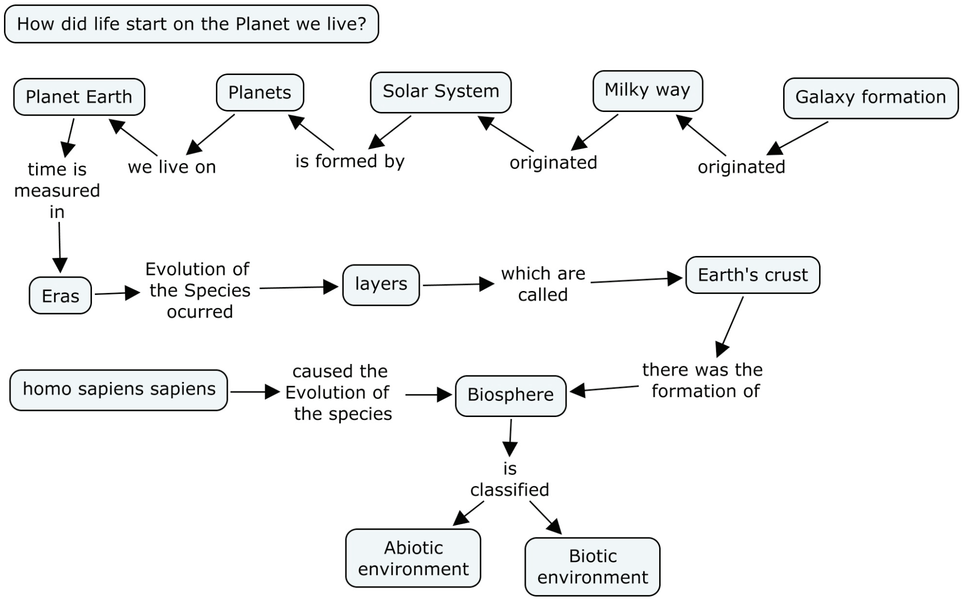

Figure 2. Concept Map produced on 10/11/2005

Figure 2 shows the first version of the concept map built by a course participant on a subject that he liked and, according to him, had some knowledge about. As the course aimed at the use of maps for the evaluation, the following interventions are evidently trying to reflect upon such objective. The first intervention regarding this production observed here was done by the course teacher.

Discussion Thread 10/18/2005 Hello, Participant Student I agree with Participant Student 2 in a particular aspect: what a work!! Navigation through your map offers information which is related to the question you have chosen as the map focus. Besides, structurally, your concept map is well built: all the relations are expressed using verbs in linking phrases. <u>As a contribution, I'd like to get an example of your map and ask you some questions: Galaxy formation- originated- Milky Way - originated- Solar System- is formed by-Planets-If that is the reading sequence , do you think we could say that: Milky Way is a galaxy? Each galaxy has a solar system? All set of planets are solar systems?</u> These are questions which could certainly explore a little the information expressed in the map and would also lead to better definitions for the concepts of Galaxy, system, and planets. What do you think? My regards, Teacher

The underlined text above reveals the teacher's choice which considers a determined sector (relationship set) of the concept map in Figure 3. This relationship system, which seems more like a text than a concept map, is approached by the teacher in a way to explore the relationship possibilities (logically plausible) between the concept pairs. It means that each set concept-linking phrase-concept can be tested separately in case the proposition is denied (Solar System – is formed by – Planets → are all the set of planets solar systems?), of the exchange of one of the concepts, or even, of establishing another link between the concepts which appear there. It is also possible to explore the combinations among the propositions. The following concept map shows some changes made after the intervention. The alternations were mainly made in the linking phrases in order to answer the teacher's questions.

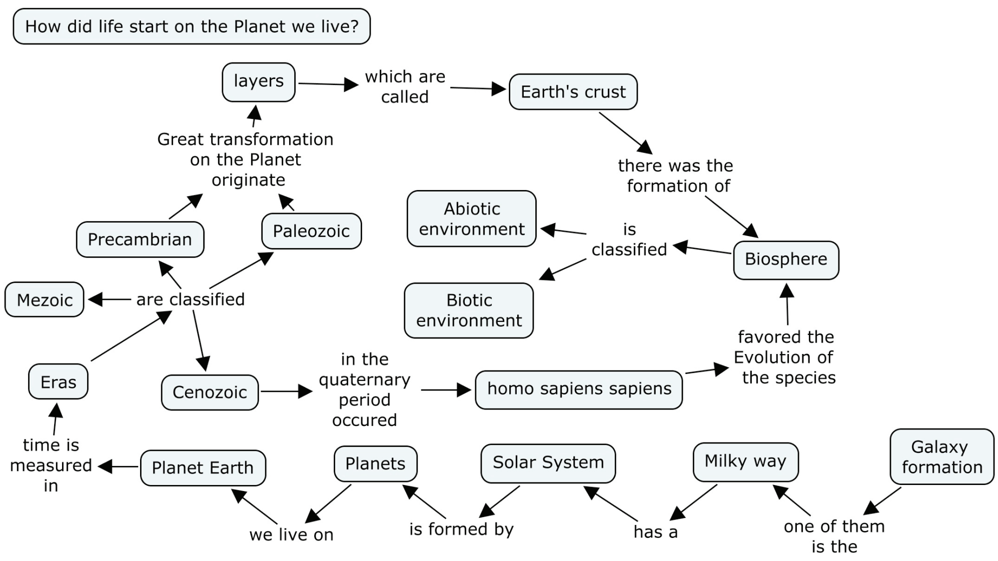

Figure 3. Concept Map produced on 10/19/2005

The following extract, still incipient when referring to the intervention, shows a awareness state from another course participant while analyzing the second version of the concept map in figure 3.

Discussion Thread 10/27/2005 Participant Student This new presentation that you've made, adding some more concepts and other linking phrases , made the map clearer. It is amazing how the construction of a MC never ends…It doesn't matter how good it is, we always look through a new point of view every time we see it. Participant Student 2

We can observe an important attempt by the student to examine an important aspect in the construction of concept maps, which certainly refers to the fact that it is always possible to explore the map relationships in a frequency which, as she notes, "never ends". It is possible to choose arbitrarily some specific points of the concept map where interventions can be made once the focus is on the process, which leads to the concept construction and not to the concept map itself as the final product. Such reflections are important for their professional practice as educators are expected to apply the knowledge constructed effectively during the course.

The analyses of both examples make it clear that the elements (synchronous and asynchronous) allow us to identify the intervention possibilities based on the interaction elements used in each course. It is observed that the interventions occur over the relationship possibilities between the students' concept map. Considering this, the activity planning needs to potencialize this type of intervention, emphasizing that there is no need for technological sophistication (in reference to the elements), focusing the evaluation of its efficiency on the participants' feedbacks.

5 Conclusions

The current literature review in respect to the investigations on the use of concept maps allowed us to analyze the study carried out by Cunha, Fernandes, Omar & Silva (2004) which presents a Cooperative Environment based on the web, which I built for the application of learning evaluation and to test it with the students, establishing an efficient evaluation with concept maps in relation to the objectives proposed by the teacher. The research line suggests that the environment built by the authors is important to help in the meaning learning evaluation. According to them, the environment stimulates the relationship among the concepts and the proposition formation among them, facilitating the construction of knowledge over a specific theme. However, we did not find in the report, criteria capable of establishing a relationship between the experiment performed and the authors' conclusions. Would it be possible for an environment to stimulate the construction of relationships among the concepts? How to consider that the relationships shown really represent the construction of knowledge?

As for Rocha, Jr & Favero (2004), they searched for an automatized analyze system of Concept Maps. They concluded that these automatic analyses can be uncertain due to the ambiguous character that the propositions in the Concept Maps can present. Their work proposes a strategy which aims at minimizing this ambiguity by the analysis of the concept inclusivity nature within the concept map hierarchy. The methodology involves the use of a program called EBNF, which makes use of a set of grammar rules which, according to the study, allows the position of the linking phrases in the concept map propositions. When attributing to such value positions related to a arbitrary grammar (here considered as a typification of possible linking phrases), the concept map processing establishes a semantic comparison measure of the different propositions , putting them together according to the grammar used and establishing their relevance and pertinence levels. In another paper (Rocha, Jr & Favero 2004b), the same authors presented a program which uses a genetic algorithm and computer ontology to compare concept maps referring to common issues (which make up the ontologies) and to offer suggestions for the users of a map digital editor (developed by the authors). As they state in a specific section of the article, this type of approach differs from the one found in the literature to promote comparisons between the set of maps and not only with the one proposed by an expert in the subject. It is a consistent and ingenious work considering the method used to measure and to compare. On the other hand, we ask: Is it enough to suggest propositions for the maps to promote concept constructions? Is it possible to establish if the meanings expressed by the subjects are equivalent only by the criteria withdrawn from the language or the semantics?

As for the actions described in this paper, the interventions presented in the previous section aimed at provoking awareness state (Piaget, 1997, 1978) by the subjects (course participants) in relation to their constructions (concept maps) and, at the same time, in relation to the strategies for the use of maps to follow the students' learning process.

The distance intervention model, which we now present, represents our first results in gathering a systematized set of orientations that lead to the production of activities and the exploration techniques for the relationship possibilities in the Concept Maps built by the course participant students offered by the MCE portal. The examples presented suggest that it is possible to potentialize the actions efficiency implemented after the identification and planning of such interventions in a way that, by the end of the activity cycles, it is possible to infer that in fact there was a change in the subjects' meaning system (Piaget, 1976b; Piaget, 1995).

Considering this, we emphasize the importance of a retroaction in the activity planning in a way that the interaction and intervention analyses allow some flexibility when re-elaborating the proposals, as well as how this planning influences the kind of teachers' intervention during the courses. The methodology presented is, therefore, built from the systematic analyze of the interactions in the courses where the interventions resulting from the activities (from the students and the teachers) help their development. Finally, it is emphasized that the need for each teacher-students to produce and to review their own concept maps, focusing the activities on the interaction over such maps. The analyses and observation results pointed out in this paper can be summarized by the following orientations:

- In respect to the activities, privilege should be given not only to the concept map construction , but mainly to the systematic revision of each map built to make the relationships more explicit among the elements (concepts in construction) involved in such productions;
- Due to the type of construction allowed by the concept maps, the record production in natural language performed by the subjects is fundamental considering the propositions contained in the production resulting from each activity (the concept maps); and
- The systematic exchanges (questions, request for clarification, interviews) related to the concept maps produced in order to obtain the point of view of the subject responsible for them are fundamental for the awareness state in respect to the relationships (or relationship systems) expressed in the maps.

The contrast between the results obtained in our study, considering other researches done, makes us believe that the first results can support the discussions and investigations that occur due to the expansion of distance education in the country, and in special, for the distance degree courses.

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A PROPOSAL TO REFINE SACMap TECHNIQUE (STRUCTURAL ANALYSIS OF CONCEPT MAPS) AMID A STS-WEBQUEST CONTEXT

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Abstract. In this research, concept maps constructed or filled in as part of a learning strategy called *injerto* in *Webquest* form are analyzed. The *injerto* strategy is based on cooperative learning, and it is associated with the Science, Technology and Society (STS) educational approach, which got adapted to the WebQuest computer strategy. In the first part of the investigation, 34 students participated, building a concept map from the question, "What evolution is?" It was then applied Cañas, Novak et al.'s proposed taxonomy, selecting level 2 maps and up for conducting content analysis on these. This analysis focused on assessing whether if the concept map proposals showed categories profiling a proper high school degree scientific topic (*definition, characteristics and examples*), or not. The second part of the research consisted of developing a map including 29 concepts and their connectors about evolution conceptually speaking, basing on a WebQuest as source. Then, 18 concepts were removed from the full map, and collected into a list also given to the students, who got the task for picking and placing the right concept in the fields of the map accordingly with their best knowledge until the map was filled up. The same map and process got applied on another 49-student group which had fully completed the evolution lesson, but never got into contact with the WebQuest. In this part of the research, we used the Structural Analysis of Concept Maps (SACMap) technique, (*Análisis Estructural de Mapas Conceptuales,* AEMC, Spanish acronym), applying the Olmstead-Tukey corner test of association (*Prueba de asociación de Olmstead-Tukey*). The WebQuest-involved students' concept maps demonstrated more accuracy concerning correct propositions for the *Characteristic* category. This suggests that the elements this category includes could serve as organizers anticipated in subsequent activities. One of the conclusions we got from the SACMap results, is that WebQuest-involved students completed the map in a similar fashion to those not involved in the WebQuest. This demonstrates that the WebQuest itself provides the required elements for learning the evolution subject's conceptual part, which supports a STS-kind education, and suggests that the teacher should only serve as guide, so the students could get the information themselves, and not as its source. A revision including modifications to the SACMap is proposed, for the situation in which an expert concept map is provided with concepts as scaffolding elements.

1 Introduction

A recent research line uses concept maps as a tool to explain and assess the way a student picks and connects different concepts with each other. Ruiz-Primo & Shavelson (1996) described a series of factors to be taken into account while using concept maps, and stressed that any given map's construction can be characterized by the kind and number of pieces given to the student for its reconstruction (Ruiz-Primo, 2004). The so called "fill-in-map" (FM) technique consists of supplying the students with a concept map from which pieces, as concepts or link-words have been taken away. Students must then complete the map placing back in the missing elements. Hernández (2005) has suggested fit to provide a missing concept list, in order to avoid semantic equivalence problems between the elements the students propose and the expert map itself. However, the disadvantage here is that the knowledge the students can manifest gets restrained and, on the other hand, it is difficult to ascertain whether if the students guess or know for sure, while picking the concepts for filling in the concept map.

A couple of our recent research works (Gonzalez, et al., 2004, Gonzalez, et al., 2006) not only got to similar results as well, but also provided evidence that the FM technique-developed concept maps are useful for detecting the presence of propositions and/or concepts considered crucial in the learning process. The evidence bases on the Structural Analysis of Concept Maps (SACMap) technique, which turns the concept map elements into a data matrix. Later on, specific rows or columns are submitted to analysis, as the Educational Structural Analysis suggests (Solano, 1989), which is the SACMap technique theoretical basis. There is another technique, called construct-a-map (CM), in which students build the concept map from the pieces given, such as concepts or link words. Results derived from other investigations (Ruiz-Primo, 2004; Yin et al., 2005) suggest that both FM and CM techniques yield in concept maps whose interpretation could not be considered as equivalent, for the technique chosen in order to fill in the maps could mislead the results.

In this paper we propose a SACMap-based methodology to gather the information generated after the completion of a map with both the CM and the FM techniques.

As part of our theoretical context, we find suitable to specify that this research was developed under the Science, Technology and Society (STS) approach, which takes into account all social factors driven by scientific and technological forces. This approach also takes into account the social and environmental consequences resulting from science and technology applications. Membiela (2001) distinguished, amidst other teaching-learning techniques in STS education: "Small group work, cooperative learning, student-focused discussions, problem solving, simulation and role-playing drills, decision-making exercises, and discussion and debate rehearsing". Osorio (2002) suggests that due to Latin American educational systems' complex nature, the *injerto* scheme is the right option.

An *Injerto* is an added theme that arises as an instructional strategy designed to ensure that students actually acquire critical assessment abilities on the consequences on society of adopting both new technologies and scientific knowledge. To achieve this, a fictitious scenario is brought in for its development in a cooperative learning framework. This instructional strategy has been analyzed and assessed basing on questionnaires, checklist and rubrics (Argos, 2008; Gordillo & Toscano, 2005), aside from the fact that there are other instruments for scientific and technological concepts assessing. We have implemented this *injerto* scheme together with concept maps (Gonzalez et al., 2006) as a tool for evaluating the students' learning of scientific concepts. In this research, we follow this line of scientific concepts-learning analysis, applying both this *injerto* technique (Garcia et al. 2001) and submitting simulated situations (Gordillo & Toscano, 2005) so the students, relying on the SACMap (Gonzalez et al. 2004 ; 2006) technique as analysis tool.

Martin-Laborda (2005) draw attention to the fact that the Information and Communications Technologies (ICT) represent a way to improve the education quality, as well as a mean for responding to the new demands the information society poses. Gutierrez (2003) has stressed that –concerning computer science, the education on these technologies should be first focused on helping the student acquire the knowledge, skills and abilities to handle these technological devices. Secondly, this training should provide the students with the required information so they could positively identify, interpret, select, evaluate and produce their own messages, from which they will find their way as active role-players in the social transformation. Thus, the incorporation of ICT strategies in STS education turns into a necessity.

On our behalf (Gonzalez et al. (2006), we have built and developed *injerto* schemes in association with the WebQuest computer-based strategy, proposed by Bernie Dodge and Tom March (Dodge, 1997). A WebQuest is an educational tool in the form of a Website that makes the students interact with Internet searching functions as they are compelled to find information on previously selected subjects by their teacher (Pérez, 2004), which is complementary and fully consistent with the *injerto* strategy (Hermosillo 2006). Cooperative learning is one of the educational features the *injerto* strategy and WebQuest share in common, which reflects in the final outcome, as the final result comes after the Web-sourced information interpretation and discussion, which involves the exposition of the group's several perspectives and opinions.

2 Methodology

The WebQuest was applied to a 16 to 17 year-old 34-student group, as initial activity of the "Evolution of living beings" lesson from the Biology IV programme. The exercise unfolds from a fictitious situation: From two different theories, the students must pick one to be officially taught in high school. Both theories address how the living creatures diversity did generate; one is a scientific-based theory (Darwin's theory of evolution), while the other (Intelligent Design) lacks of any scientific basis whatsoever. A specific profile and role to represent was given to each one of the students on behalf of one theory or the other. On the role assigning, a special case were the reporters', for the students playing TV reporter role were not supposed to act on behalf or any theory, however, playing their role required acquaintance on both theories in order to undertake their reporting function.

The WebQuest's instructions and source materials were provided to students through two Internet sites: The http://sulfobio.blogspot.com blog and http://mx.youtube.com/sulfobio video sharing site page. The exercise was developed in six 50-minute sessions, consecutive some of these. The sessions took place in February's third week, 2008. The students grouped accordingly with the theory they supported and role they played (Scientific researchers, Educational Council members, Officials, Sponsors and TV Reporters). Scheduled interviews were conducted on each one of the several sectors. In these interviews, everyone had to listen to each interviewee and pay attention to his or her arguments on behalf of –or against, each one of the theories. Finally, an individual and group reflection on the original question: "*Which one of these biodiversity theories should be officially taught in high school?"* was conducted as conclusion of the exercise.

Since building concept map was a rather frequent learning strategy during the course, this student group was already familiar with it. As initial instruction in class, the students were asked to construct a concept map from the question *"What evolution is?"* Once the group finished constructing the map, they were told to browse the Internet blog in search for the instructions and information they will later on require. During the WebQuest's final session, the students were asked to construct a map from the same question. Both maps were done accordingly with the CM construction technique.

Basing on the information available at the http://fai.unne.edu.ar/biologia/evolucion/evo1.htm, http://fai.unne.edu.ar/biologia/evolucion/evo2.htm, http://fai.unne.edu.ar/biologia/evolucion/seleccion.htm Websites (included in the Internet blog), the authors of this research developed an *expert concept map* including 29 concepts and their respective links as shown in Figure 1. Based on previous analyses (Gonzalez et al., 2006) the authors removed 18 concepts from the map, leaving only 11 shown in gray boxes in Figure 1. During the WebQuest's last session, once the students finished building their CM map, they were furnished with the *expert concept map*, with blank boxes and a list of the missing concepts, alphabetically sorted, so they could fill in the map picking the concepts from the list. This map was created accordingly with the FM construction technique. As comparison mechanism, the expert concept map was given to a 49-student group whom had recently finished the "Evolution of living beings" course. This group had never participated in any WebQuest-type activity. After each one of both groups (the one participating in the WebQuest, and the one not involved in it) finished solving the FM map, they were asked to answer the question: *"What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?"*

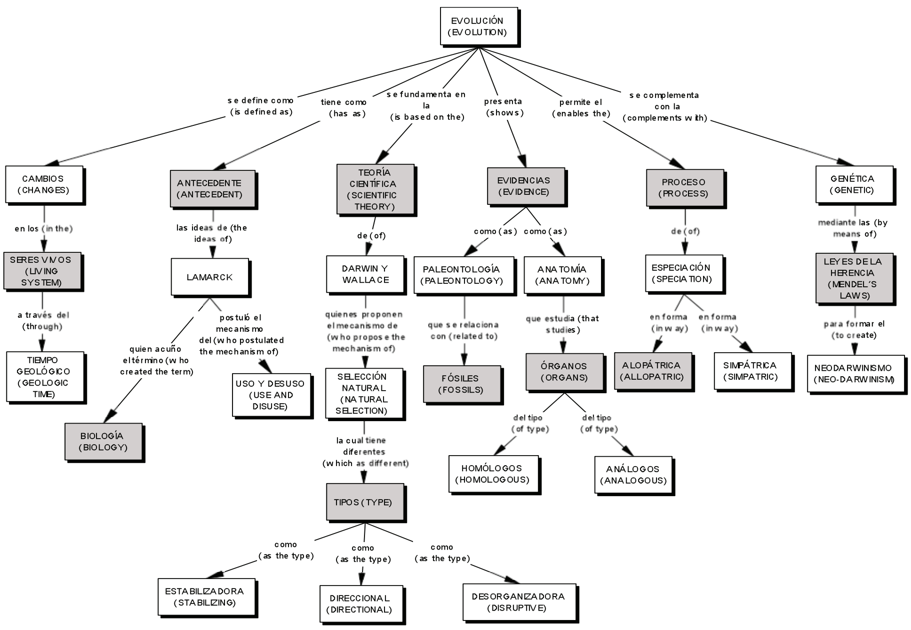

Figure 1. Expert concept map drafted by the authors hereof. Concepts and link words appear in Spanish with their respective translation into English in parenthesis.

We applied the SACMap technique (Gonzalez et al., 2004 and 2006) for analyzing the completion the students did on the expert concept maps. For the CM-type maps, we applied the methodology Cañas, Novak *et al.* (2006) suggested, which proposes a tool for interpreting the concept maps basing on their own topological structure and complexity. The expert concept map includes a classification (taxonomy) based on seven levels (0 to 6) and five criteria: a) concepts are used instead of text, b) the setting of relations connecting concepts, c) the branching degree, d) the hierarchy depth, and e) the cross-linking presence. Accordingly with the authors here of: "The taxonomy was developed (...) for researching purposes only", and "hasn't been designed as a concept map qualifying tool."

Taking the aforesaid into account, this topological taxonomy was used only as a classification instrument that worked in a discriminating way letting the authors set apart all level 2 and up concept maps, which were later taken into consideration for former analysis as only level 2 and up would be herein useful for their content interpretation in terms of topological and structural complexity and degree. Accordingly with Campos, Cortes & Gaspar (1999), any scientific concept identifies by a set of attributes reflecting a set of descriptive and/or explicatory components in association with a specific scientific theory, in such way that, in addition of a proper designation of a concept, a fitting description and examples of it must accompany. For the case of our content analysis, we consider that a proper addressing of the "What evolution is?" question by means of a concept map must include a definition of the evolution theory, its characterization, and examples on the subject. Such were the criteria for the CM maps content analysis. As part of the CM and FM maps analysis process, a series of different χ^2 tests were applied.

3 Results

Thirty four (34) students participated in the WebQuest; 65% female and 35% male. In comparison, from 49 students not participating in the WebQuest 51% were female and 49% male. The results of applying Cañas, Novak *et al.*'s (2006) topology demonstrated that 21 out from the 34 maps (62%) made at the beginning of the WebQuest, scored with minimum required level 2, while at the WebQuest's last stage, 27 out from the 34 maps (72%), scored with minimum required level 2. Table 1 shows both frequency and percentage values obtained after analyzing the students' concept maps' content done before and after taking the WebQuest. Right proposition percentage is higher at the last stage of the WebQuest (53% against 83%); in a mostly general way the χ^2 test indicated an important difference ($\chi^2 = 7.09$; gl=1, $p<0.05$). Analyzing the right propositions in the definition, characteristic and example categories it was clear that only *characteristic* category had a significant increase in its right proposition percentage (21% to 49 %; $\chi^2 = 7.6$; gl=1, $p<0.05$).

Two group matrixes were generated from the concept maps the students completed, accordingly with the SACMap technique. Table 2 shows the matrix corresponding to the WebQuest-participating group's maps. We decided not to include herein the second matrix showing the maps of those students not participating in the WebQuest due to space considerations. The correct relation frequency of the box in gray in each group matrix was translated into percentage values, starting from the assumption that the maximum value of each box in gray equals the total maps completed by the students (34 for those who did participated and 49 for those who did not). Accordingly with the SACMap technique, such percentages must be taken to the expert map as shown in figure 2. We found no significant differences ($\chi^2 = 10.1$; gl=27, p=0.05; 40.1) after applying the χ^2 test on the right proposition frequency values among both the WebQuest participating and non-participating students.

	WebQuest – participating group		
	frequency (percentage)		
Category		**Before implem./n(34)**	**After implem./n(41)**
Definition			
	right	**9(26)**	**14(34)**
	wrong	**3(9)**	**1(2)**
Characteristics			
	right	**7(21)**	**20(49)**
	wrong	**11(32)**	**5(12)**
Examples			
	right	**2(6)**	**0(0)**
	incorrect	**2(6)**	**1(2)**
Total			
	right	**18(53)**	**34(83)**
	wrong	**16(47)**	**1(4)**

Table 1. Frequency and percentage values resulting from the content analysis of the concept maps constructed before and after the WebQuest implementation.

		ALOPATRIC	ANALOGOUS	ANATOMY	ANTECEDENT	BIOLOGY	CHANGES	DARWIN AND WALLACE	DISRUPTIVE	DIRECTIONAL	SPECIATION	STABILIZING	EVIDENCE	EVOLUTION	FOSSILS	GENETICS	HMOLOGOUS	LAMARCK	MENDEL'S LAWS	NEODARWINISM	ORGANS	PALEONTOLOGY	PROCESS	NATURAL SELECTION	LIVING SYSTEMS	SIMPATRIC	SCIENTIFIC THEORY	GEOLOGIC TIME	TYPES	USE AND DISUSE	Total relations	Frequency of relationship	% Frequency of relationship
1	ALOPATRIC																														0	0	0
2	ANALOGOUS																														0	0	0
3	ANATOMY														1						33										34	2	7
4	ANTECEDENT							1										33													34	2	7
5	BIOLOGY																														0	0	0
6	CHANGES	1																							32	1					34	3	10
7	DARWIN AND WALLACE					1					5					1				2				26							35	5	17
8	DISRUPTIVE	1																								1					2	2	7
9	DIRECTIONAL	1																								1					2	2	7
10	SPECIATION	18																	1						1	18			5		43	5	17
11	STABILIZING																														0		0
12	EVIDENCE			34																		34									68	2	7
13	EVOLUTION				34		33				2		34			30				1			34	3			34				205	9	31
14	FOSSILS																														0	0	0
15	GENETICS	2																	30							2			1		35	4	14
16	HMOLOGOUS	1																								1					2	2	7
17	LAMARCK					33	1				1									1								1		27	64	6	21
18	MENDEL'S LAWS											1				1				30										1	33	4	14
19	NEODARWINISM																		1					1					1		3	3	10
20	ORGAN		34														33	1													68	3	10
21	PALEONTOLOGY														33						1										34	2	7
22	PROCESS						1		1	1	18					2	1							4		1		1		4	34	10	34
23	NATURAL SELECTION	4								1									2						1	3			27		38	6	21
24	LIVING SYSTEMS																											32		2	34	2	7
25	SIMPATRIC	1										1																			2	2	7
26	SCIENTIFIC THEORY							33												1											34	2	7
27	GEOLOGIC TIME	1																								1					2	2	7
28	TYPES								32	32	5	32														1					102	5	17
29	USE AND DISUSE	4																								4					8	2	7
	MEDIAN																														34		8.5

Table 2. Matrix of the WebQuest participating student group. Gray boxes correspond to the concept links from the expert concept map.

"What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?" Table 3 describes the results of this question sorted by answer category. The results

derived from the χ^2 test later applied on the frequency values of both the WebQuest participating and non-participating groups showed an important difference ($\chi^2 = 21.5$; gl=4, $p<0.05$). We can highlight the fact that the WebQuest-participating group mentioned the *extra-classroom activities* (41%) and *the in-classroom activities* (23%) as their main information sources for completion of the map. These students considered visiting the sites recommended in the Internet blog (web pages and videos) as *extra-classroom activities*, while they considered the WebQuest activities themselves, such as team and group discussions and debates, as *in-classroom activities*. On the contrary, students not involved with the WebQuest mentioned the *in-classroom activities* (42%) and the *not directly related to the class activities* (24%) as their main information sources for undertaking the task. This student group mainly considers their school teacher guidance as *in-classroom activities*, and they mentioned activities such as watching TV shows, surfing web pages and reading books and magazines found at home as *not related to the class activities*.

	Student groups frequency (percentage)	
Category	**WebQuest parti cipati**	**non-WebQuest parti cipati**
Extra-class acti vity	33 (41)	17 (15)
In-class acti vity	18 (23)	48 (42)
Background school	14 (18)	19 (17)
Not-related to the class acti vity	11 (14)	28 (24)
Other	4 (5)	3 (3)

Table 3. Answers to the question *What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?"* from WebQuest participating and non-participating student groups. Answers are sorted by category.

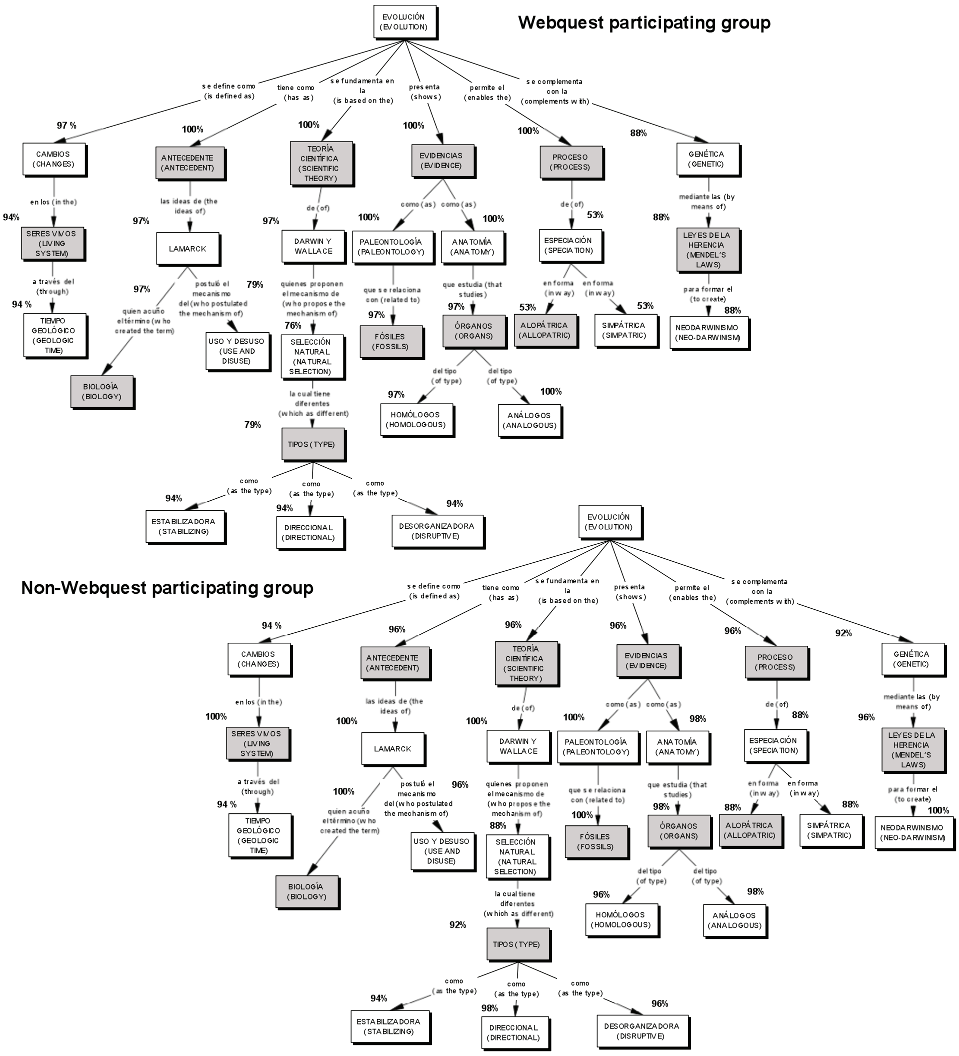

Figure 2. Representation of WebQuest participating and non-participating groups' concept maps

Table 4 and Figure 3 show the Olmstead-Tukey Test results, which, accordingly with the SACMap technique, is the other outcome derived from the afore mentioned two matrixes. Later, the expert concept map was compared with those the students completed in terms of relation number and frequency. For starters, it was necessary to create a brand new category *(Terminal)* additionally to the other four that we used *(Dominant, Occasional, Constant, and Rare)*. This is due as once the expert map is analyzed, some concepts such as Geologic Time appear to be left without any relation with any other. On the other hand, terminal concepts (Biology, Fossils and Allopathic) were not included in the analysis for these were given to the students with expert map; these appear in gray boxes in Figure 1 y 2.

Therefore, these terminal concepts appear in the matrix as empty lines. Additionally, another difficulty derived from the analysis was that six other concepts were left without classification, for they stood at the quadrants' limits, as shown in Figure 3 and described in Table 4. Accordingly with the obtained results from the expert map, *Dominant* is the only category that could be used. Because of this, both the WebQuest participating and non-participating student groups did identified the three concepts (Speciation, Evolution, Lamarck) but also included other non-Dominant concepts, as described in the expert map.

WebQuest parti cipati ng studer

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
GENETIC	NEODARWINISM		DISRUPTIVE	ANALOGOUS
DARWIN AND WALLACE			DIRECTIONAL	STABILIZING
NATURAL SELECTION			HOMOLOGOUS	
SPECIATION			SIMPATRIC	
LAMARCK			GEOLOGIC TIME	
EVOLUTION			USE AND DISUSE	
dominant/constant concep		*occasional/rare concep*		
CHANGES		ANATOMY		
		PALEONTOLOGY		

WebQuest non-parti cipati ng studer

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
CHANGES	STABILIZING		ANATOMY	ANALOGOUS
SPECIATION			DISRUPTIVE	DIRECTIONAL
EVOLUTION			HOMOLOGOUS	NEODARWINISM
GENETIC			GEOLOGIC TIME	SIMPATRIC
LAMARCK				USE END DISUSE
NATURAL SELECTION				
		occasional/rare concep		
		DARWIN AND WALLACE		
		PALEONTOLOGY		

Expert map

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
SPECIATION				ANALOGOUS
EVOLUTION				DISRUPTIVE
LAMARCK				DIRECTIONAL
				STABILIZING
				HOMOLOGOUS
				NEODARWINISM
		occasional/rare concep		SIMPATRIC
		ANATOMY		GEOLOGIC TIME
		CHANGES		USE AND DISUSE
		DARWIN AND WALLACE		
		GENETIC		
		PALEONTOLOGY		
		NATURAL SELECTION		

Table 4. WebQuest's evolution concepts classification, describing both participating and non-participating groups' classification. This table includes the expert map-based concept classification.

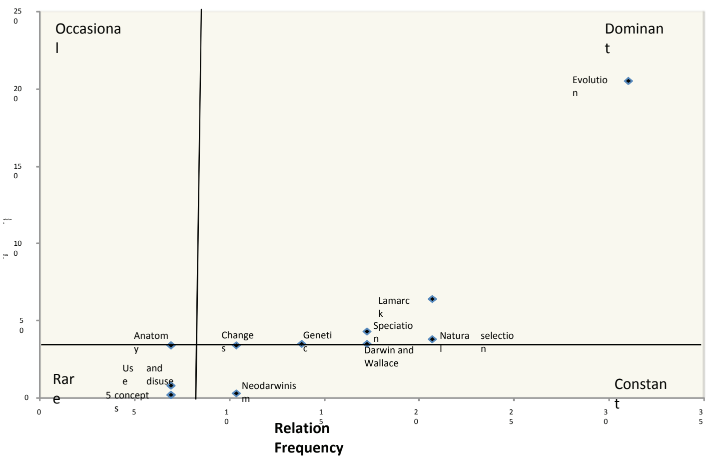

Figure 3. WebQuest participating group's concept classification basing on the results of a set of Olmstead-Tukey tests of association.

4 Discussions and Conclusions

About the interpretation of the concept maps made by WebQuest participating students, more right propositions at the last stage for the *Characteristics* category were noticed. In a previous research, (González *et al.,* 2006) it was mentioned that the evidence found from the FM type concept maps suggested that the WebQuest should be carried out at the beginning of the didactic unit or lesson. The information provided by the CM maps support this conclusion. Moreover, it indicates which learning categories of a scientific discourse (to define and exemplify) require to be reinforced by the teacher with later activities. A former, more precise analysis on the propositions set in the maps by the students would indicate which, among the characteristics they mention, could be used as anticipated organizers in activities following the WebQuest.

In this regard, while applying Cañas, Novak *et al.*'s (2006) taxonomy onto the maps reduced the size of the model for its content analysis, it helped interpreting maps in an easier way, as having a minimum level of typology enabled us identify three categories (to define, characterize and identify) in the maps. An alternative explanation could be that, aside from the used strategy, there will be an increase in the maps' typological level as natural result of addressing a topic.

A conclusion derived from the SACMap results is that both the WebQuest participating and non-participating students completed the expert map in an equivalent form. The interpretation is that both groups had the same capabilities for identifying and setting the concepts in the expert concept map. Previously (Gonzalez et. al, 2006), we found out that, in spite of the fact that the *injerto* is focused on value learning, its own activity sequence and structure leads the student to identify and locate the propositions of scientific concepts in a most general way. In this research, the *injerto* was incorporated to the WebQuest with a visual source of information, such as videos and web pages. WebQuest participating students remarked that their information source was the Internet, and that watching videos were their main source actually. In-classroom WebQuest's activities (analysis and discussion of the information) were also important, they said. However, most of WebQuest non-participating students said that their information main source had been their teacher, and a minority said that it had been a non-scholar information source. The application of the ICT in the education process proposes that the teacher should play designer, administrator and counselor roles for those activities making learning easier. The teacher then must serve as guide so the students could find the information themselves, instead of being the source of it. The student-completed maps made in the framework of this research demonstrated that the WebQuest itself provided the students with all the required tools for learning the Evolution topic conceptual part at this school grade.

However, after undertaking an analysis through the Olmestead-Tukey Test, we found that the outcome did not contribute with a clear interpretation of the student-completed concept maps. In our opinion, this is due to the modification applied in the expert concept map. This modification consisted in removing a series of concepts in order to provide these separately to the students so they could then complete the map with them as a strategy of scaffolding. The expert map architecture yielded a variety of situations such as: a) a new category (Terminal), which includes concepts from the expert map's higher hierarchical level that -according to the SACMap technique, do not establish any relationship with any other category of inferior levels, so they are outside from the boundaries of the analysis; b) the lack of values in the categories of Constant, Occasional and Rare; and c) the inability for classifying categories belonging to certain concepts (Occasional or Rare). In a previous research on mother cells (González *et al.,* 2006) none of the aforementioned situations occurred, as the expert map given to the students lacked of any concept working as scaffolding element, which modified the right completion probability basing only on the map's own architecture. Therefore, concerning the SACMap technique, we can affirm that using expert concept maps including elements designed as previous organizers, it is very recommendable to previously evaluate the expert map by the Olmstead-Tukey Test before involving the students with it. This evaluation will consist on obtaining a theoretical prediction on which concepts of the expert map will be assigned to each one of the four categories (Dominant, Constant, Occasional and Rare), basing on the number of propositions they establish when related to other concepts. The number of concepts given in the expert map as scaffolding elements must also be taken into account. If there were concepts not ascribable to any given category or ascribable only to the Terminal category, the required modifications on the expert map's architecture would be necessary in order to prevent this situation.

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A SEMANTIC SCORING RUBRIC FOR CONCEPT MAPS: DESIGN AND RELIABILITY

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Abstract. At Panama's *Conéctate al Conocimiento* Project there was the need to develop measurement tools to help assess the Project's overall progress towards the goal of implementing the use of concept maps for meaningful learning in the country's public elementary schools. Efforts in this direction led to the development of a taxonomy for concept maps consisting of two components, a topological taxonomy, and a semantic scoring rubric. The topological taxonomy, along with a study of its reliability, was described in an earlier article. The complementary semantic component is presented in this paper. In view of the greater subjectivity involved in the assessment of map content as compared to structure, this tool was expected to be significantly less reliable. Nonetheless, results of our reliability study, conducted among Conéctate Project facilitators, showed an encouraging level of agreement, particularly in the linearly-weighted percent agreement.

1 Introduction

Conéctate al Conocimiento (Tarté, 2006) is arguably the most ambitious education reform project ever implemented in the Republic of Panama. The aim is to fundamentally transform the way children learn in Panamanian public schools, leaving behind the traditional model based almost exclusively on memorization in order to move towards more meaningful modes of learning.

Much of the effort at the Conéctate Project is directed to training teachers in concept mapping, as a means to foster meaningful learning in their students. Facilitators, the heterogeneous group of professionals in charge of teacher training, also visit schools to offer educators support in bringing about the desired changes. During the Project's first year (2005), it was difficult to determine the level of success that was being attained because reports coming in from facilitators were highly subjective. This was aggravated by the fact that the maps created by teachers and students ranged over a very wide spectrum – from the extremely simple to the highly complex – and by the lack of a common language, shared by all facilitators, in which to express all this variety. Thus the Project was in dire need of an objective measurement tool, one that would allow us to gauge more accurately and precisely the extent to which concept maps were actually contributing to meaningful learning processes.

This state of affairs led, in 2006, to an effort to design a tool that would "measure the level of progress in the representation of concept maps, beginning with simple maps, with linear sequences of concepts and texts in nodes, and without linking phrases; all the way to maps with clear propositions, good cross-links, linked to relevant resources and to other maps" (Cañas *et al*, 2006, p. 154). We sought a *taxonomy for concept maps*, similar to Bloom's (1956) taxonomy for cognitive domain skills.

Given that concept maps of novice mappers often could not be read meaningfully, due primarily to the presence of large portions of text and/or absence of linking words, we opted to separate our taxonomy into two components, one topological, dealing with the structure of the graphical representation, the other semantic, dealing with the content.[1] The *topological taxonomy* (Cañas *et al.,* 2006) considers 5 criteria: concept recognition, presence of linking phrases, depth, ramification, and presence of cross-links. The classification consists of 7 levels, ranging from 0-6. Levels 0-2 are considered "poor" topologically speaking due to presence of long texts, absence of linking phrases, and essentially linear sequences of concepts. Level 3 maps are deemed "acceptable," since they show a clear recognition of individual concepts and linking phrases are not missing; however, they show only moderate ramification and depth, and no cross-links. Level 4 maps are essentially "good" maps; their main limitation is that they are missing cross-links. Levels 5-6, both of which include cross-links, are considered "very good" maps topologically speaking. A more detailed description of the taxonomy, along with the results of a reliability study conducted among Conéctate facilitators, may be found in Cañas *et al*. (2006). In this article we present the semantic component.

2 Semantic component of the concept map taxonomy

In keeping with the design behind the topological taxonomy, our idea was to produce a *semantic taxonomy* that would serve to classify concept maps based on increasing levels of semantic complexity and quality of content.

[1] The idea, however, was that as mappers became more skilled in accurately representing their ideas in the form of a concept map, the topological component would become unnecessary.

Not surprisingly, developing a satisfactory tool to categorize maps semantically proved to be considerably more challenging than designing one to classify them by structure. Unlike topology, where there is little room for interpretation, semantics entails dealing with meanings, and meanings are always personal and idiosyncratic. An additional complication was the "one-size-fits-all" design requirement we imposed on the tool, that is, it had to be applicable to all domains of knowledge and adaptable to many levels of expertise.

Thus, although our original intention was to produce a classification system by levels of increasing semantic complexity, preliminary testing of the categorization we had come up with proved unsatisfactory. Given the specific semantic criteria we had selected, as well as the levels we had defined based on these criteria, we found that semantic complexity did not necessarily progress in an even fashion across all criteria for all learners, as was generally the case in the topological arena. In any given concept map, some semantic aspects might be quite advanced or well-developed, while others remained at a basic level.

Given the context of our work and the rather urgent need for the tool, we decided to go forward with a point-based evaluation scheme or rubric. Such a scheme had the advantage of not penalizing learners for their asymmetric progression towards semantically more complex concept maps. A correspondence was then set up between score ranges and overall content quality, thus yielding the required categorization. Nonetheless, the question remains as to whether it is possible to come up with a reliable classification system based on increasingly complex semantic levels, akin to our topological taxonomy, valid for all learners, independently of the different paths their concept mapping learning process follows.

There exist in the literature numerous systems for the evaluation of concept maps. These are essentially of three types: *component-based scoring* (e.g., Novak & Gowin, 1984), *comparison to expert or criterion maps* (e.g., Ruiz-Primo & Shavelson, 1996), and *hybrids* or combinations of the previous two systems (e.g., Rye & Rubba, 2002). Perhaps the most widely known is Novak & Gowin's component-based scoring model which assigns points based on 1) number of valid relationships, 2) number of valid conceptual hierarchy levels, 3) number of valid and significant cross-links, and 4) number of valid examples (ibid, p. 37).

Our own semantic scoring system, described in the following section, belongs to the component-based category. However, it includes criteria not considered in Novak & Gowin's rubric, some of which stem from our own experience with Panamanian teachers and students at the Conéctate Project, as well as from recent theoretical considerations put forth by Cañas & Novak (2006), directed at making better use of the representational power of concept maps. It also draws from ideas found in Derbentseva, Safayeni, & Cañas (2004); Safayeni, Derbentseva, Cañas (2005); and Novak & Cañas (2008).

We wish to call attention to the fact that we do not consider this rubric a "finished" instrument; as most measurement tools, it will require redesigning and calibration in order to improve its accuracy and reliability. Modifications are being considered as of this writing. Nevertheless, the tool (as presented in this paper) was applied (Miller, 2008) to a sample of more than 500 concept maps produced by teachers being trained at Conéctate, with a number of interesting results (see Miller & Cañas, 2008; Beirute & Miller, 2008); hence, our interest in making it public as used.

3 The semantic scoring rubric

The semantic scoring rubric developed at the Conéctate Project is intended to be applied only to concept maps containing sufficient structural and semantic elements to be read meaningfully. This essentially means that individual concepts predominate over undifferentiated texts, and that propositions are not missing linking phrases. Roughly, concept maps with a topological level of 3 or greater meet these requirements.

Our semantic rubric takes into account the following six criteria: 1) concept relevance and completeness, 2) correct propositional structure, 3) presence of erroneous propositions (misconceptions), 4) presence of dynamic propositions, 5) number and quality of cross-links, and 6) presence of cycles. In what follows we discuss each of these in turn.

In deciding concept relevance and completeness, external, contextual factors such as the author's personal background (including age, education level and culture) play an important role. For instance, what one would consider a fairly complete list of concepts on the topic of, say, photosynthesis, is not necessarily the same for a 4th grade student as for a teacher. A second aspect to consider is the source or sources of the map's content. A map may be based entirely on previous knowledge; or it may use a specific pedagogical experience, such as a reading, a film, an experiment, or a school visit, to build upon previous knowledge.

Additionally, within the map itself various elements can guide the evaluator in assessing relevance and completeness of concepts. First and foremost, the root concept. One can be fairly certain that this element is always available since at Conéctate teachers are taught to construct maps stemming from a given root concept; thus, it is never the case that a map contains no root concept. A second guiding element is the focus question. This element is less reliable though, since sometimes the question is omitted, or ends up bearing no relation whatsoever to the root concept or the map's content. One may also consider those concepts nearest the root concept. This can be helpful if there is no focus question or the question is not related to the root concept. Though all these elements can certainly help, there is no way around the fact that this criterion involves a great deal of subjectivity,[2] and hence one would expect it to contribute much of the variation among evaluators.

The second criterion involves recognition of propositions as independent semantic units. Propositions are characterized first, by their structure, generally triads of the form *concept – linking phrase – concept*; and second, by being meaningful and transmitting a complete idea. Not all triads constitute propositions. A triad fails to be a proposition if 1) it lacks the proper structure; 2) it does not make logical sense; or 3) it is not autonomous, i.e., it is a fragment or continuation of a larger grammatical structure such as a sentence, and has no meaning independently of this bigger structure.

This emphasis on correctly structured propositions is not simply a groundless whim. Propositional structure is essential to concept mapping. Requiring a person to make explicit relationships between concepts, be they previously known concepts, newly acquired, or a combination thereof, can foster a process of higher order thinking, essential to meaningful learning. Following the evolution of propositions over a given time span, furthermore, can help visualize the process of meaningful learning as revealed by subsumption, progressive differentiation and integrative reconciliation of concepts; link reworking; and overall map reorganization.

The third criterion deals with erroneous propositions, that is, propositions that make false assertions relative to some objective standard – misconceptions. In the present scheme, the occurrence of erroneous propositions is not penalized; their absence is rewarded. In applying this criterion, it is important to distinguish between relations that result in false statements due to misconceptions – true conceptual errors – and those that may arise from incorrect propositional structure. The tool is designed to give learners the benefit of the doubt by first requiring correct propositional format in order to assess truth value. Additionally, in applying the scoring rubric to a concept map, the evaluator must take into account the nature of a map's content: objective versus subjective. This consideration is essential since propositions in maps whose content is subjective usually can not be judged by objective standards.

The next criterion concerns the static/dynamic nature of propositions. Our definition of static and dynamic propositions was inspired by the corresponding notions of static and dynamic relationships defined by Safayeni *et al.* (2005), but we have made certain changes. For us a proposition is considered to be dynamic if it involves physical movement, action, change of state, or it establishes some form of dependency relationship. We consider the presence of dynamic propositions important since "the ability to represent both static and dynamic relationships in a single map may increase the power of the representational system (ibid, p. 2)."

Dynamic propositions may be causative or non-causative. In causative propositions one of the concepts must be associated to the "cause" or "probable cause" while the other must be associated to the "effect." Cause-effect propositions, in turn may be quantified or non-quantified. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept. Propositions which are not dynamic are static. Static propositions generally "help describe, define and organize knowledge for a given domain" (Safayeni *et al*., 2005, p. 10). Examples to help clarify these distinctions may be found in the appendix.

Number and quality of cross-links is the next criterion. From a topological perspective, the interest was mainly on the presence of cross-links. Now, from the viewpoint of content, the emphasis is on whether these cross-links establish correct, suitable, and instructive relationships. The number of cross-links, however, is also important. In our view, a good map should have at least three distinct[3] cross-links. In choosing a specific number like 3, we are guided by our experience which suggests that 1 or 2 cross-links can usually be established

[2] It is probably the most subjective of all 6 criteria.
[3] By this we mean that they do not use the same linking phrase.

without too much difficulty, but a more deliberate effort is needed to find more of these horizontal relationships. As for an upper bound, the guiding principle is whether no important and/or evident relations have been left out.

The final criterion concerns the presence of cycles in the concept map. A cycle is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction. As Safayeni *et al.* (2005) observe, cycles enable "the representation of dynamic functional relationships among concepts. A cycle is built from a constellation of concepts, which represents a group of closely interconnected constructs. Cyclic Cmaps [or Cmaps that contain cycles] capture interdependencies or how a system of concepts works together." Though cycles constitute an important element of Cmaps, the presence of cycles does not necessarily imply a better map; moreover, acyclic maps may actually be very good. Thus, in our taxonomy, the distribution of points is such that acyclic maps can still belong to the highest semantic level, provided they attain a sufficiently high score in all other criteria.[4]

Once points are assigned for each of these six criteria, they are added to obtain a raw numeric score, which is then translated into a 6-level content-quality scale with the following categories: *unevaluated*[5], *very low*, *low*, *intermediate*, *high,* and *very high*.

Besides the factors already mentioned that may influence the objective application of the semantic rubric, factors pertaining to the evaluator, variables such as education, personal preferences, knowledge of the map's topic, and attitude toward the evaluation task, can further bias the application of the tool. For all these reasons, we expected rather low agreement amongst facilitators in our reliability study. To our surprise, our study showed an encouraging level of inter-rater agreement.

4 Reliability study for semantic scoring rubric

The reliability study we conducted for our semantic scoring rubric was quite similar to the reliability study carried out earlier for the topological taxonomy (Cañas *et al.,* 2006). The study consisted of two stages: the first stage provided valuable feedback that served to refine the instrument; the second stage yielded the reliability statistics we sought, namely, the *percent agreement* and the *kappa coefficient*, unweighted and linearly weighted.[6] Evaluators were Conéctate facilitators, all whom share a common understanding of concept mapping.

4.1 Methods and procedures

Twelve facilitators volunteered to participate in the initial exploratory stage. Given the complexity of the scoring scheme, the tool was discussed with the evaluators prior to beginning; the discussion was followed by a brief practice session during which one map was analyzed semantically. The evaluators were then given 10 concept maps to evaluate. The reason for this small sample size was to avoid fatigue, which we knew had been a factor with the validation of the topological taxonomy, and was even more likely to play a role in this study, where the evaluation task demanded greater cognitive exertion.

Results and evaluator feedback from this first trial indicated the need to clarify descriptions for some criteria and to completely revise others. The revised taxonomy was used in the second phase of the study, which took place in December 2006 with the participation of all available Conéctate facilitators, a total of 33. A second, completely new set of 10 concept maps was used. This set was selected at random from a universe of 25 concept maps, 5 from each semantic level except the "unevaluated" level, that is, maps that do not meet the minimum criteria to be read meaningfully. Once again, the tool was discussed with all participating evaluators prior to beginning the evaluation.

4.2 Results

Results yielded an average percent agreement among evaluators of 47.2%, with a 95% confidence interval of (46.0%, 48.5%). The unweighted *kappa* coefficient was 0.29, (0.27, 0.30), and the linear-weighted *kappa* coefficient was 0.50, (0.49, 0.51), representing *fair* to *moderate* agreement,[7] respectively.

[4] In the sample of over 500 teacher maps evaluated by Miller (2008), the fraction containing cycles was practically null. Hence, one of the modifications being considered at present is the elimination of this criterion.
[5] This level is assigned to those maps that do not meet the basic requirements to be read meaningfully mentioned earlier.
[6] Percent agreement represents the average, over all possible pairs of evaluators, of their pairwise agreement; the *kappa* statistic attempts to factor out agreement due to chance.
[7] Interpretation of *kappa* values is based on Landis and Koch's (1977) table.

In order to identify the levels between which the greatest dispersion occurred, we considered the distribution of all 5,280[8] possible pairs of evaluations of the set of 10 concept maps by 33 facilitators (table 1). We found that the largest disagreements were between consecutive levels (values immediately below the main diagonal). For instance, 16% of the 5,280 evaluations resulted in one evaluator in a pair assigning a given map to level 1 while the other evaluator assigned it to level 2; between levels 3 and 4, the value was 10%, and between levels 2 and 3, 9%. These percentages help explain the improvement in the linear weighted *kappa* statistic relative to the unweighted *kappa*. Nonetheless, discrepancies by 2 levels (values along the second diagonal below the main one) are non-trivial, which accounts for the overall low *kappa* values.

As table 1 shows 39% of all pairs of evaluations resulted in disagreements by differences of exactly 1 level, while 86% of these pairs resulted in disagreements by differences of at most 1 level. This is quite a good result, considering the inevitable subjectivity involved in the evaluation of content and the complexity of the measurement tool.

Evaluation by facilitator A	Evaluation by facilitator B						
	Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
Level 0	**0%**						
Level 1	1%	**30%**					
Level 2	0%	16%	**6%**				
Level 3	0%	4%	9%	**7%**			
Level 4	0%	0%	5%	10%	**4%**		
Level 5	0%	0%	1%	3%	3%	**1%**	
Level 6	0%	0%	0%	0%	0%	0%	**0%**
Subtotal	**1%**	**50%**	**21%**	**20%**	**7%**	**1%**	**0%**

Table 1. Distribution of the 5,280 possible pairs of evaluations of 10 concept maps evaluated by 33 facilitators.

Once the results were computed, a feedback session was conducted with the evaluators to inform them of the study's outcome and to obtain their impressions regarding the tool. This session led to further revisions of the scoring rubric. The version resulting from these refinements is presented in the appendix to this article.

5 Concluding remarks

This paper discussed the design of the semantic component of a 2-part taxonomy for concept maps. The original goal of coming up with a classification system, akin to the one developed for the topological taxonomy, could not be realized given that, for our particular choice of criteria, we found that our subjects progressed unevenly towards maps of greater semantic quality and sophistication. Hence, practical considerations led us to design a point-based scoring rubric based on the selected criteria. The rubric draws from Novak & Gowin's (1984) original scoring scheme, but also from more recent ideas that seek to increase the representational power of concept maps through the inclusion of dynamic propositions and cycles, as well as from our experience in working with Panamanian schoolteachers. In spite of the complexity and inevitable subjectivity implicit in the tool, our reliability study, carried out with facilitators from the Conéctate Project, indicates a moderate level of consistency among evaluators sharing a common understanding of concept maps.

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[8] There are [(33*32)/2] = 528 distinct pairs of evaluators and 10 maps for each pair to agree or disagree on.

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APPENDIX

SEMANTIC SCORING RUBRIC FOR CONCEPT MAPS

This semantic scoring rubric is meant to be applied to concept maps that, for the most part, contain no texts nor lack linking phrases. When it is deemed that a map does not meet the requirements to be evaluated semantically, it is given a total score of 0 and assigned to the category of "unevaluated" concept maps. In tailoring the tool to a specific concept mapping task it is important to take into account the author's personal context: age, educational level, cultural background, etc., as well as the instructional setting in which construction of the map takes place (e.g., based on readings, videos, plays, experiments, field trips), and the objective/subjective nature of the content. This is particularly important for criteria 1 and 3.

This tool was designed to provide a reasonable guide to content evaluation in the context of Panama's Conéctate Project. Occasionally, strict adherence to the scoring rubric will not necessarily result in the fairest or wisest evaluation of a map's content. Thus, in applying this rubric it is important to keep in mind the 'spirit' of the various criteria, in addition to their exact wording.

CRITERION # 1: **Concept relevance[1] and completeness**
Note 1: *Relevance and completeness is determined, first, in relation to the* ***root concept****; second, the* ***focus question*** *(if there is one and the root concept corresponds to it); third, the* ***concepts closest to the root concept*** *(if there is no focus question or the root concept is not related to focus question).*
Note 2: *If several concepts appear within a single box, but clearly identified as individual concepts (for instance, separated by commas or marked by vignettes) they are counted as separate concepts.*

0 pts. The map contains very few concepts and/or most concepts are irrelevant, redundant or not well-defined (e.g., "characteristics" instead of "physical characteristics"); additionally, there is an excessive use of examples (one third or more of the map's concepts are examples).[2]
1 pts. One half or more of the map's concepts are relevant and well-defined, but many important concepts are missing; and/or there is an excessive use of examples (one third or more of the map's concepts are examples.
2 pts. Most concepts are relevant and well-defined, but some important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).
3 pts. All concepts are relevant and well-defined; no important concepts are missing. Appropriate use of examples (less than a third of the map's concepts are examples).

CRITERION # 2: **Propositions as "semantic units"[3]**
Note 1: *In the case of examples, it is permissible to use linking phrases such as: "like", "for example", "such as", etc.*
Note 2: *If the map contains a small number of propositions (excluding examples) or the map does not contain second level propositions,[4] this must be taken into account in the determining the score. The maximum number of points should only be given if the map provides sufficient evidence that its author truly understands the notion of proposition as a "semantic unit" in the sense previously defined.*

The author does not understand how to construct propositions (very few propositions are well constructed).
0 pts. The author understands somewhat how to construct propositions (some propositions are well constructed).
1 pts. The author understands how to construct propositions (all or almost all propositions are well constructed).

CRITERION # 3: **Erroneous propositions**
Note 1: *Only propositions and examples validated under criterion # 2 are considered.*
Note 2: *Erroneous propositions resulting from incorrect use of the CmapTools software are not considered.*

0 pts. The map contains more than 2 erroneous propositions.
1 pts. The map contains 1-2 erroneous propositions.
2 pts. The map contains no erroneous propositions.

CRITERION # 4: **Dynamic propositions[5]**
Note 1: *Only propositions validated under criterion # 2 are considered.*
Note 2: *This criterion is independent of criterion # 3; that is, erroneous dynamic propositions are counted.*

0 pts. The map contains no dynamic propositions of any kind.
1 pts. The map contains only **non-causative** dynamic propositions.
2 pts. The map contains 1-2 **causative** dynamic propositions with **physically separate links[6]**.
3 pts. The map contains more than 2 **causative** dynamic propositions with **physically separate links**.
4 pts. The map contains **quantified causative** dynamic propositions.

CRITERION # 5: **Quantity and quality of cross-links**
Note: *Only propositions validated under criterion # 2 are considered.*

0 pts. The map contains cross-links, but they are all erroneous (false).
1 pts. The map contains no cross-links.

2 pts.	The map contains cross-links and these establish correct (true) relationships. However, they are redundant or not particularly relevant or adequate.
3 pts.	The map contains 1-2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.
4 pts.	The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. However, based on the concepts present in the map, important and/or evident cross-links are missing.
5 pts.	The map contains more than 2 correct, relevant and adequate cross-links with **physically separate links**. Based on the concepts present in the map, no important or evident cross-links are missing.

CRITERION # 6: **Presence of cycles**[7]

0 pts.	The map contains no cycles.
1 pts.	The map contains at least 1 cycle, but **some propositions in the cycle do not satisfy criterion # 2**.
2 pts.	The map contains at least 1 cycle and **all propositions in the cycle satisfy criterion # 2**.

Levels:

Unevaluated	0	Intermediate	9 – 11
Very low	1 – 5	High	12 – 14
Low	6 – 8	Very high	15 – 18

NOTES

[1] A concept is considered irrelevant if: 1) it is not related to the topic under consideration; or 2) it is related to the topic, but does not contribute substantially to it. One way to decide whether a concept is irrelevant is to think of removing it from the map and ask ourselves if this alters the map's content significantly (in relation to the root concept and the focus question). If our answer is "no", it is quite likely that this particular concept is not relevant to this map.

[2] Examples are specific instances or occurrences of concepts. For instance, "Chagres River" is an instance of the concept "river". Examples are usually joined to concepts by the following linking words: "for example", "like", "such as", among others.

[3] A triad is **not a proposition** if 1) it lacks the required structure CONCEPT + LINKING PHRASE + CONCEPT; 2) it does not make logical sense, either because its meaning depends on previous propositions, or due to grammatical mistakes, incorrect use of CmapTools, or some other reason; 3) it is not autonomous, i.e., it is clearly a fragment or continuation of a larger grammatical structure.

[4] A **second level proposition** corresponds to the second linking phrase counted from the root concept.

[5] **Dynamic propositions** involve: 1) movement, 2) action, 3) change of state, or 4) dependency relationships. They are subdivided into **non-causative** and **causative** dynamic propositions. In causative propositions, one of the concepts must clearly correspond to the cause while the other one clearly corresponds to the effect. Causative propositions, in turn, may be **quantified**. Quantified propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept.

- Examples of non-causative dynamic propositions: *Roots absorb water*; *herbivores eat plants; digestive system breaks down food product; living beings need oxygen*.
- Examples of causative dynamic propositions: *Electric charge generates electric fields*; *reproduction allows continuity of species*; *cigarettes may produce cancer*; *independent journalism strengthens credibility*; *exercise decreases risk of developing diabetes*; *rule of law attracts foreign investment*.
- Examples of quantified causative dynamic propositions: ***Increased** transparency in public affairs **discourages** corruption*; ***under-activity** of the thyroid gland (hypothyroidism) **decreases** body metabolism*; ***increased** quality of education contributes to **greater** national development*.

Static propositions, on the other hand, serve only to describe characteristics, define properties and organize knowledge. They are generally associated to linking phrases such as: "is", "are", "have", "possess", "are made up of", "are classified into", "are divided into", "contain", "live", "are called", "is located in", "likes", etc.

- Examples of static propositions: *Sun is a star*; *means of transportation include land transport means*; *Panama is located in Central America*; *animals may be vertebrates*.

[6] By propositions with "p**hysically separate links"** we mean propositions that use distinct linking entities (boxes) to join one concept to another. However, the linking words within these separate boxes may be repeated.

[7] A **cycle** is a directed circuit in which the direction of the arrows allows traversing the entire closed path in a single direction.

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A SUPPORT TO FORMALIZE A CONCEPTUALIZATION FROM A CONCEPT MAP REPOSITORY

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Abstract. Operations focused on the integration and filtering of concepts and propositions from various concept maps are presented as a Concept Maps Query Language (CMQL), representing a novel approach to automatically obtain knowledge from a concept map repository. Additionally, the mapping between concept maps and ontologies is described as a formal transformation method, which semantically analyzes the relationships among concepts in the map. A context in which CMQL can be useful is as support in the construction of the concept map (conceptualization) to be formalized in a preliminary ontology.

1 Introduction

In most scientific domains, information needs sometimes to be analyzed and processed by machines. In the knowledge representation oriented to the semantic analysis and processing by machines, context in which a certain degree of formalization is required, the development and use of *ontologies* is increasingly common. In this paper, we adopt the following definition for *ontology*: a formal and explicit specification of a conceptualization, which is readable by a computer; which is derived from Gruber (1993), Borst (1997) and Studer et al. (1998). *Concept maps* (CMs) are human-friendly, graphically-rich tools for organizing and representing knowledge (Novak & Gowin, 1984), and several works suggest that ontologies and CMs can be integrated (Gómez, Díaz, & González, 2004; Hayes, Eskridge, Saavedra, Reichherzer, Mehrotra, & Bobrovnikoff, 2005; Brilhante, Macedo, & Macedo, 2006).

Concept mapping is a knowledge elicitation technique that consists of enumerating a list of concepts and determining the *linking-phrases* that should connect the concepts to form meaningful propositions. This process can be carried out semi-automatically, when the system retrieves information and suggests concepts, relationships between concepts, or propositions to a human (Reichherzer, Cañas, Ford, & Hayes, 1998; Cañas, Hill, Carff, Suri, Lott, Gómez, Eskridge, Arroyo, & Carvajal, 2004; Richardson, Goertzel, & Fox, 2006), or automatically, when the CM is constructed without the aid of a human. In any case, the use of some information source, such as texts (Richardson, Goertzel & Fox, 2006), the Web or CM repositories (Cañas, Hill, Carff, Suri, Lott, Gómez, Eskridge, Arroyo, & Carvajal, 2004), is required. In case a CM repository is used as information source, the set of query operations that can be used for information retrieval has not been formally defined in the literature. Eskridge et al. (2006) argue that CMs are very good at organizing knowledge about a wide variety of subjects; however, they present some difficulties when it comes to the retrieval of concept maps based on individual query terms. Moon et al. (2006) report how to integrate many CMs to create a new CM that they call "master map", doing it in part manually, and in part using CmapTools (Cañas, Hill, Carff, Suri, Lott, Gómez, Eskridge, Arroyo, & Carvajal, 2004). From a study of the current state of the art, the authors believe that efforts should be dedicated to extend the scope of knowledge management in relation to CM repositories.

In this paper, we propose an extension of the process reported by Simón et al. (2008) to obtain a formal preliminary ontology from a CM. Specifically, a CM query language (CMQL) to be applied to a CM repository is proposed in order to support the user in obtaining a *conceptualization* (e.g., a CM to be transformed into a preliminary ontology). The CMQL defined here can be useful to the *knowledge engineering process* that is carried out for the creation of ontologies from CMs, in which obtaining *potentially useful knowledge* (coming from existing knowledge) for the construction of the conceptualization by the user or the knowledge worker is a required task. The CMQL allows users and knowledge workers to know about *concepts* and *propositions* that have been shared by other users in a CM repository, through several operations focused on the integration and filtering of *concepts* and *propositions*. The result of these processes is represented in a new CM.

The paper begins with an overview of ontologies and the languages defined to formalize them (section 2). In section 3, the process of obtaining a conceptualization from a set of CMs is studied and a query language to achieve this is formally presented; an example is included for better understanding. Section 4 describes the basic aspects of the CM-ontology mapping according to the formalization method reported by Simón et al. (2008); an example, in which the portion of the CM formalized is obtained from a query operation of CMQL, is again included for better understanding. Finally, the comparison with the state of the art is reported in section 5.

2 Ontologies and their languages

In artificial intelligence, ontologies were introduced to share and reuse knowledge. They provide the common reference frame for communication languages in distributed environments (such as multi-agent systems or the semantic Web) and a formal description for automatic knowledge processing. Several languages have been defined to implement them; OWL (Smith, Welty, & McGuinness, 2004) is the latest, standardized ontology language. OWL is based on RDF and RDFS, and includes three specifications, with different expressiveness levels: OWL Lite, OWL DL and OWL Full. The code obtained by the method described in this paper is generated according to OWL DL specifications. OWL DL is so named due to its correspondence with *description logics*. *Description logic* (DL) is the name for a family of knowledge representation formalisms that represent the knowledge of a domain by first defining the relevant concepts of the domain (its terminology), and then using these concepts to specify properties of objects and individuals occurring in the domain (Baader & Nutt, 2003). The terminology specifies the vocabulary of a domain, which consists of concepts and roles, where the concepts denote individuals while roles denote binary relationships between individuals.

3 Obtaining knowledge from concept maps

In this section, the operations for obtaining knowledge from a CM repository are studied and a formal query language (CMQL) to achieve this is presented. The result of the application of each operation is the automatic construction of a new CM. The system retrieves information (*concepts* and *propositions*) from a repository of CMs, through the following operations:

1. union of a CM set;
2. intersection of a CM set;
3. closed sub-map, guided by a concept set;
4. open sub-map, guided by a concept set;
5. open sub-map of radio R, guided by a concept set;
6. closed extension of a CM, guided by another CM and a concept set;
7. open extension of a CM, guided by another CM and a concept set;
8. open extension of radio R of a CM, guided by a concept set.

For the information retrieval in the repository, the system uses one or several of the query operations included in CMQL. The information that is retrieved from the repository is formed by *concepts* and *propositions*, and is expressed as the automatic construction of a new CM, in which those *concepts* and *propositions* are related. The query operations defined in CMQL are formalized in terms of the combination of graph theory and set theory, and may have as input one or more CMs (and a concept set in some cases) (as shown in Table 1). The CM is represented as a *directed graph* (Johnsonbaugh, 1999), that is, $G = (V, E)$, where V is the set of vertices (*concepts*) and E the set of directed edge (*propositions*). This allows taking advantage of the operations that have been defined in both fields (graph theory and set theory) for the automatic processing of CMs.

Basic definitions:
M^x is a concept map, $M^x = (C^x, P^x)$; *c* is a concept;
C^x and CS are concept sets;
P^x is a proposition set, $P^x = \{\ldots, (c_o, l\text{-}p_j, c_d), \ldots\} \mid l\text{-}p$ is a *linking-phrase* and $c_o, c_d \in C^x$;
CMS is a set of concept maps.

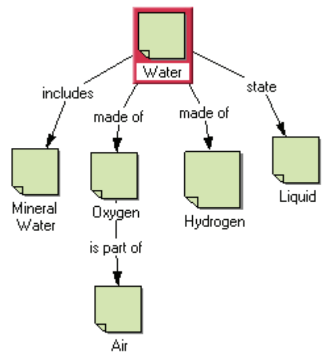
Query operations	**Expression**	**Results**
Union of a CM set	$UM(CMS) = \cup M^i \mid M^i \in CMS$	A new CM formed by: all *concepts* and *propositions* represented in the CMs included in CMS.
Intersection of a CM set	$IM(CMS) = \cap M^i \mid M^i \in CMS$	A new CM formed by: the *concepts* presented in all CMs in CMS, and the *propositions* in which they are related.
Closed sub-map, guided by a concept set	$SM^-(M^x, CS) = M^{x \cap y} \mid M^y = (CS, \{\})$	A new CM formed by: • the common *concepts* between CS and M^x; and • the *propositions* in M^x in which they are related.

Open sub-map, guided by a concept set	$SM^+(M^x, CS) = M^1 = (C^1, P^1) \mid P^1 = \{(c_o, l\text{-}p_j, c_d) \mid (c_o, l\text{-}p_j, c_d) \in P^x, c_o \in (CS \cup C^x) \vee c_d \in (CS \cup C^x)\}, C^1 = \{c_i \mid (c_i, l\text{-}p_j, c_d) \in P^1\} \cup \{c_i \mid (c_o, l\text{-}p_j, c_i) \in P^1\}$	A new CM formed by: • the *concepts* in CS and their neighbors in M^x (Two concepts are neighbors if they are related by a proposition.); • the *propositions* in M^x in which the previous concepts are related.
Open sub-map of radio R, guided by a concept set	$SM^{+,R}(M^x, CC) = \begin{cases} SM^+(M^x, CC) & \text{si } R = 1 \\ SM^{+,R-1}(M^x, C1),\ M1 = (C1, P1) = SM^+(M^x, CC) & \text{si } R>1 \end{cases}$	A new CM formed by: • the common *concepts* between CS and M^x and all *concepts* in M^x to which a path with length ≤ R can be created from some concept in CS; • the *propositions* in M^x in which those concepts are related.
Closed extension of a CM, guided by another CM and a concept set	$Ext^-(M^x, M^y, CS)$	A new CM formed by: • the *concepts* in M^x and the *concepts* included in the CM obtained from $SM^-(M^y, CS)$; • the *propositions* in M^x and the *propositions* included in the CM obtained from $SM^-(M^y, CS)$.
Open extension of a CM, guided by another CM and a concept set	$Ext^+(M^x, M^y, CS)$	A new CM formed by: • the *concepts* in M^x and the *concepts* included in the CM obtained from $SM^+(M^y, CS)$; • the *propositions* in M^x and the *propositions* included in the CM obtained from $SM^+(M^y, CS)$.
Open extension of radio R of a CM, guided by another CM and a concept set	$Ext^{+,R}(M^x, M^y, CS)$	A new CM formed by: • the *concepts* in M^x and the *concepts* included in the CM obtained from $SM^{+,R}(M^y, CS)$; • the *propositions* in M^x and the *propositions* included in the CM obtained from $SM^{+,R}(M^y, CS)$.

Table 1: CM query operations included in CMQL

The CM query operations allow automatically obtaining a new CM, which can be edited later by the user, from knowledge represented in other CMs. This is a novel contribution with respect to current retrieval proposals, in which *concepts* and *propositions* are retrieved independently and have to be integrated by the user (Cañas, Hill, Carff, Suri, Lott, Gómez, Eskridge, Arroyo, & Carvajal, 2004). With the proposed method, CMs developed by persons focused on different aspects of a domain can be integrated, as in the case of "master maps" (Moon, Pino, & Hedberg, 2006), which can be automatically obtained using the operation *Union of a CM set*.

As an example, six query operations (intersection, union, open sub-map, closed sub-map, open extension and open extension of radio R) are applied to the simple CMs shown in Figure 1 and 2. Results are shown in Figures 3-8.



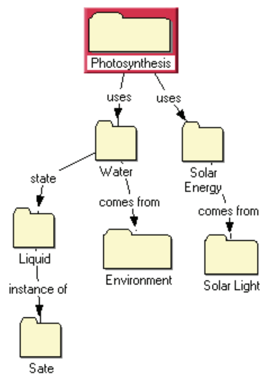


Figure 1. CM about "Water" **Figure 2.** CM about "Photosynthesis"

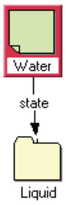


Figure 3. Intersection of Water's CM and Photosynthesis's CM:

IM({Water, Photosynthesis})

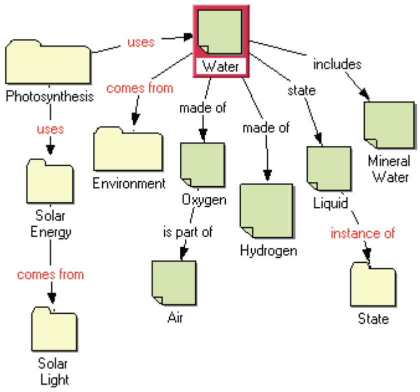


Figure 4. Union of Water's CM and Photosynthesis's CM:

UM({Water, Photosynthesis})

Figure 5. Open sub-map of Water's CM, guided by Oxygen and Air concepts:

SM^{+}(Water,{Oxygen, Air})

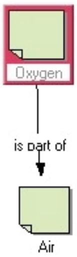


Figure 6. Closed sub-map of Water's CM, guided by Oxygen and Air concepts:

SM^{-}(Water,{Oxygen, Air})

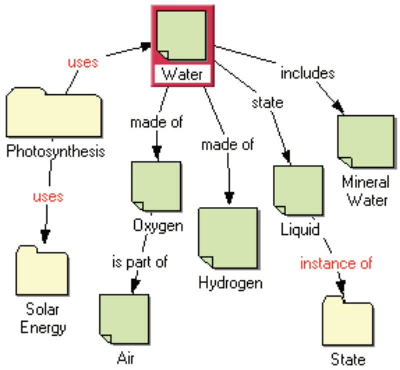


Figure 7. Open extension of Water's CM, guided by Photosynthesis's CM and by Photosynthesis and State concepts:

Ext^{+}(Water, Photosynthesis, {Photosynthesis, State})

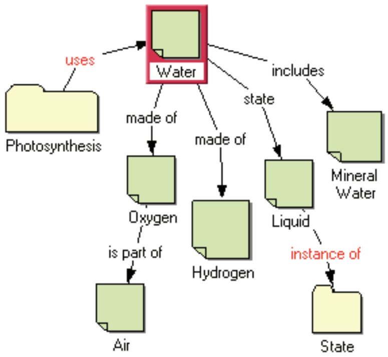


Figure 8. Open extension of R = 1 of Water's CM, guided by Photosynthesis's CM and by Photosynthesis and State concepts:

Ext$^{+,1}$(Water, Photosynthesis, {Photosynthesis, State})

CMQL allows the user to know about *concepts* and *propositions* that have been shared by other users in the CM repository and provides the capability for the analysis of the interrelations of existing knowledge. The availability of this type of operations may be used as an indicator of the potential inference capability of a given CM tool kit. The CMQL defined can be useful to obtain a *conceptualization* from a CM repository, which may be later translated into OWL in order to formalize the informal knowledge of a CM into an ontology.

4 Basic aspects of CM-OWL mapping

Knowledge, in OWL ontologies, is expressed as *classes*, *subclasses*, *properties* and *instances* (Smith, Welty, & McGuinness, 2004), while in CMs much of this formal and explicit specification does not exist, and has to be inferred. Nonetheless, some initial structural mapping between CMs and OWL can be easily established:

- *Concepts* correspond to: *classes* and *instances*;
- *linking-phrases* correspond to: *properties*, considering this as a binary relation between instances of classes in OWL (Smith, Welty, & McGuinness, 2004);
- *propositions* correspond to *classes* and *properties' restrictions* or other OWL constructs.

Some type of semantic relation, such as *class-subclass*, *class-property*, *class-property-value*, *class-instance*, can be inferred from certain *linking-phrases* used in CMs, in accordance with others authors (Hayes, Eskridge, Saavedra, Reichherzer, Mehrotra, & Bobrovnikoff, 2005; Brilhante, Macedo, & Macedo, 2006). In this section, how to map a CM (synthesized from a CM repository with the use of CMQL) to an ontology will be described.

In addition to the CM to be formalized, two external knowledge sources are used in this work: WordNet (Miller, Beckwidth, Fellbaum, Gross, & Miller, 1990) and another CM repository. WordNet is a lexical knowledge base, whose basic structure is the *synset. Synsets* form a semantic network and are interconnected among themselves by several types of relations, some of which are used in the proposed algorithm, such as *hypernymy-hyponymy* (class/subclass) and *meronymy-holonymy* (part/whole). The *synset* defines the meaning of a word, which, in the case of *polysemy*, can be found in various *synsets*. WordNet can be used as an ontology if its links are associated to a formal semantics. The CM repository used here is the included in ServiMap (CMs Server) (Simón, Estrada, Rosete, & Lara, 2006), which stores several CM of different domains constructed using the Macosoft CM editor (Simón, Estrada, Rosete, & Lara, 2006).

The mapping and semantic inference leading to OWL coding are carried out combining (Simón, Ceccaroni, & Rosete, 2008) the analysis of:

– the syntax of the *propositions;*
– the occurrence of similar semantic relations in WordNet and the external CM repository.

Initially, some frequently used *linking-phrases* are defined and organized in four *categories*, according to the semantics that can be associated to them and their correspondence with the semantic relations in WordNet. They are:

– *Classification (CC)*, for *linking-phrases* that may indicate *(super class - class)* relations between concepts in a *proposition* (e.g., *includes*) in the proposition *(Water, includes, Mineral Water)* in Figure 1); corresponding to *hypernymy* and *hyponymy* relations in WordNet;
– *Instance (IC)*, for *linking-phrases* that may indicate *(class-instance)* relations between concepts in a *proposition* (e.g., *instance of* in the proposition *(Liquid, instance of, State)* in Figure 2);
– *Property (PC)*, for *linking-phrases* that may indicate *(class-property)* relations between concepts in a *proposition* (e.g., *has*); corresponding to *has_meronym* and *has_holonym* relations in WordNet;
– *Property-Value (PVC)* for *linking-phrases* that may indicate *(class-property-value)* relations between concepts in a *proposition*, such as nouns (e.g., *state* in the proposition *(Water, state, Liquid)* in Figure 1); corresponding to basic *meronymy* and *holonymy* WordNet's relations, and different from the more specific *has_meronym* and *has_holonym* relations (e.g. *has_mero_madeOf* and *has_holo_madeOf*).

This method allows everyday natural language to be used at CM construction time. Lexemes are used to avoid duplications due to verb forms' variability. The *linking-phrases* are continually and automatically enriched: if the proposition's semantics is inferred by some semantic relations from WordNet, then the *linking-phrase* used in this proposition is added to the corresponding category.

In the mapping method, the CM under consideration is analyzed as a structured text. A concept sense-disambiguation algorithm (Simón, Ceccaroni, & Rosete, 2007) with 89.9 % accuracy, is used to infer the most rational sense (in terms of WordNet's *synsets*), for the concepts in the CM. Once inferred a *synset* for each concept in a *proposition*, the semantics of the CM relation among them can be inferred, through a similar semantic relation between the *synset* of these *concepts* represented in WordNet (if one exists).

The method for obtaining OWL-DL ontologies form CM is organized in three phases (Simón, Ceccaroni, & Rosete, 2008): *preprocess*, *mapping* and *codification* and four components are defined for the implementation of the system:

– *parser*: it analyzes the CM to be translated to OWL, identifying propositions and their parts (*concepts* and *linking-words*) and obtains knowledge related to the CM from a CM repository;
– *disambiguator*: it infers the most rational *sense* (in terms of WordNet *synsets*) of the concepts in the CM, using the algorithm defined by Simón et al. (2007), and identifies the semantic relations between these *synsets* in WordNet;
– *semantic interpreter*: it applies a set of heuristic rules on the propositions obtained by the *parser*, to infer several semantic descriptions from the CM, such as: *classes*, *relations between classes*, *relations between classes and instances*, *property restriction (by value)*, *object properties*, *symmetric and functional properties*, *union classes* and *intersection classes*.

– *OWL codifier*: it uses the semantic description inferred by the *semantic interpreter* and writes out the corresponding OWL constructs according to W3C recommendations (Smith, Welty, & McGuinness, 2004).

As an example, we use the CM shown in Figure 7, which was obtained as result of the query operation *Open extension* on the *Water* CM (shown in Figure 1). This is a case in which a user needs to obtain an ontology about *water*; he has some knowledge about it, which allows him to construct the CM shown in Figure 1, but his needs require more information. In this situation, the query operation *Open extension* is used to enrich the *Water* CM with related knowledge that has been shared by other authors in a CM repository, which has only one CM (the *Photosynthesis* CM) in this case. A new CM (shown in the Figure 7), extending the *Water* CM, is automatically constructed. Finally, the *OWL codifier* is used to obtain an ontology from the CM:

```
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns="http://www.owl-ontologies.com/unnamed.owl#"
xml:base="http://www.owl-ontologies.com/unnamed.owl">
<owl:Ontology rdf:about="Water"/>
<owl:Class rdf:ID="Hydrogen"/>
<owl:Class rdf:ID="Oxygen"/>
<owl:Class rdf:ID="State"/>
<owl:Class rdf:ID="Air"/>
<owl:Class rdf:ID="Photosynthesis"/>
<owl:Class rdf:ID="Solar Energy"/>
<State rdf:ID="Liquid"/>
<owl:Class rdf:ID="Water">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#state"/>
      <owl:hasValue rdf:resource="#Liquid">
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#made of"/>
      <owl:someValuesFrom rdf:resource="#Hydrogen"/>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#made of"/>
      <owl:someValuesFrom rdf:resource="#Oxygen"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Mineral Water"/>
   <rdfs:subClassOf rdf:resource="#Water"/>
</owl:Class>
<owl:ObjectProperty rdf:about = "#hasPart">
   <rdfs:domain rdf:resource="#Air"/>
   <rdfs:range rdf:resource="#Oxygen"/>
</owl:ObjectProperty>
```

5 Related work

Gómez et al. (2004) report a transformation mechanism from CM into OWL language, to apply in the case-based reasoning context. In that mechanism, the CM is constructed by a user and is coded in XTM (XML Topic Maps) (Biezunski, Newcomb, & Bryan, 2002): *concepts* and *linking-phrases* are represented by *topic* tags and the *propositions* are represented by *association* tags (using the label of *linking-phrases* in the proposition as identified), and a set of rules for obtaining OWL are applied to it. In the OWL coding process, *topics* corresponding to *concepts* are coded as *owl:class* and the ones corresponding to *linking-phrases* are coded as *owl:ObjectProperty*, and *association* tags (corresponding to *proposition*) are coded as *property restriction*s*: by value*. XTM is a language lacking explicit semantics; therefore the direct mapping from XTM to OWL is very limited without a previous semantic analysis of the relations in the CM. COE is a collaborative ontology environment (Hayes, Eskridge, Saavedra, Reichherzer, Mehrotra, & Bobrovnikoff, 2005), which includes a mechanism of visualization-generation of OWL ontologies based on CM. Several graphical conventions (*templates*) are used to specify the semantics of *concepts* and *propositions* in the concept mapping. A set of *linking-phrases* is predefined to represent types of relations between concepts, e.g., "are" and "is a" (to represent class relations); "at most" and "at least" (to represent cardinality restrictions) and "cannot be" (to define negation). These aspects are oriented to increase the formalization of the CM by restricting the natural language to be used in the concept mapping. COE can show concepts from existing ontologies that are relevant to COE user's current focus; it search through some existing ontologies to locate potentially useful, contextually relevant concepts, to aid the user's comprehension of existing ontologies and lead to "fortuitous" reuse opportunities (Hayes, Eskridge, Saavedra, Reichherzer, Mehrotra, & Bobrovnikoff, 2005). Brilhante et al. (2006) report a method to translate an individual CM into an ontology. The translation is carried out by employing several heuristic rules designed to establish the representational correspondences between CMs features and OWL constructs. Concepts and relations in CMs are mapped into *classes*, *object properties*, *property restrictions* and *individuals*. The process is based on a set of predefined *linking-phrase*, e.g., "has a", "has part", "is part of" (to identify composition relations) and "is a", "can be" (for the identification of subclasses and superclasses), and on the use of *hypernymy* and *meronymy* relations from WordNet. In this approach the authors do not consider the concept's ambiguities in the use of WordNet; therefore the efficiency and effectiveness in the use of it can be low in several cases.

6 Conclusions

To realize a semantic Web, tools are required that allow users with little technical background to generate their own ontologies and collaborate in the construction of distributed knowledge bases. The work presented here is an extension of a method to formally obtain ontologies codified in the OWL-DL language from an informal knowledge representation, such as concept maps. In this paper, operations focused on the integration and filtering of concepts and propositions from various concept maps are presented as a query language (CMQL), representing a novel approach to obtain knowledge from a concept map repository. The query language presented allows the user to know about concepts and propositions that have been shared by other users in the repository, in order to support the user in obtaining a *conceptualization*. At the current state of development, the application of the operations presented may generate meaningless and contradictory propositions in the new maps constructed, for consistency and sense checking is not yet implemented; we are considering this aspect as future work. The formalization method presented advances the state of the art through the use of CMQL, as an alternative to automatically obtain potentially useful knowledge from a CM repository. The use of tools and techniques from natural language processing, such as the use of WordNet and a concept sense disambiguation algorithm, are other contributions of the formalization method presented. This, combined with the topological analysis of concept maps, allows maintaining a greater flexibility and more independence during concept mapping, which is an important aspect for less-expert users in ontology construction. Additionally, the increase in the formalizations level of the *linking-phrases* and the use of external knowledge representations, allow to augment the semantic description inference in concept maps and to obtain more expressiveness in the resulting OWL than the ones reported by other authors.

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A UNIQUE USE OF CONCEPT MAPS AS THE PRIMARY ORGANIZING STRUCTURE IN TWO UPPER-LEVEL UNDERGRADUATE BIOLOGY COURSES: RESULTS FROM THE FIRST IMPLEMENTATION

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Abstract. Constructing Concept Maps (CMaps) allows students opportunities to: (i) create "meaning" (Novak 1998) about a concept; (ii) invest in their own personalized knowledge of a topic or reading, and (iii) develop team-building skills when working collaboratively (as they do in my classes). When these opportunities are provided in an iterative manner, students are exposed to an empowering learning experience. The objectives of this paper are two-fold: (i) to describe my two learner-centered upper-level undergraduate biology courses in which CMaps are the primary organizing structure of the courses, and (ii) to assess the efficacy of my CMaps courses using three different assessment tools (thereby providing triangulation of assessment). In my two CMaps courses, students collaboratively construct a CMap, an accompanying written summary page, and a reference page for each major theme covered in the course based on readings from the textbook and scientific literature. I serve as a facilitator of learning by providing guided inquiry in these innovative courses that do not have traditional lectures or traditional assessments (exams). An analysis of the change in structure from the first "What is Ecology?" CMap to the final "What is Ecology?" CMap reveals that students gained a knowledge base in Ecology and improved their CMap building skills over the course of the semester. An analysis of students' perceptions of my CMaps courses reveals that students perceived that construction of CMaps facilitated their overall understanding of course material, yet the students' perception of the usefulness of this learning tool was context-dependent. Students responded that my CMaps format was better than the Traditional Lecture (TL) format for learning scientific literature, but ranked CMaps and TL formats equally useful for learning textbook material. Despite the context-dependence perception, most students responded that CMaps format: (i) was superior than TL format in helping them develop thinking skills; (ii) envisioned constructing CMaps for other courses or scientific literature readings (showing transference by students); and (iii) preferred these courses continue in the CMaps format. An analysis of students' comparison of my CMaps courses to TL courses using Novak's (1998) "5 Elements of Teaching" CMap, reveals that students perceive both course formats emphasize the concept "knowledge". Students perceive TL courses also emphasize "teacher" and "disempowering". Students perceive my CMaps courses emphasize "empowering", "learner", and "interact" (in addition to "knowledge"). I conclude that my collaborative CMaps courses provide students with deep, meaningful, and empowering learning opportunities.

1 Introduction

Learner-centered practices place the responsibility and rewards of learning on the student, with the teacher guiding the learning process, fostering a conducive learning environment, and providing examples or explanations of relevant experiences (Weimer, 2002; Blumberg, 2004 & 2008). Social interactions between students (as peer collaborators) and the teacher (as a facilitator) are central to this pedagogy. In this environment, the teacher reflects on and designs meaningful exercises that focus on the: (i) context of learning; (ii) content of what is to be learned; (iii) retention of material; (iv) application and transference of knowledge; and (v) relevance of this knowledge for the students' future (Weimer, 2002).

Concept Map (CMap) construction provides a creative cognitive tool for organizing knowledge about concepts in a hierarchically structured, non-linear, visual format in which concepts are connected with lines and accompanying linking words to form propositions (Novak & Gowin, 1984; Novak, 1998; Novak & Cañas, 2008). This learning tool is based in social constructivist learning theory, in which learning is a self-regulated building of concepts upon a scaffold of previous knowledge (von Glaserfeld, 1995; Biggs, 1999; Bransford et al., 2000). Constructivist teaching and learning requires reflection about the concept, abstraction of knowledge into one's own meaning, and acceptance of personal value of this meaning and process (von Glaserfeld, 1995; Biggs, 1999; Bransford et al., 2000; Novak & Cañas, 2008). When students work collaboratively "knowledge is socially produced by consensus among knowledgeable peers" (Barkley et al., 2005, p. 6). Therefore, collaborative construction of CMaps by students should promote "deep, meaningful" (Biggs, 1999; Bransford et al., 2000; Barkley et al., 2005; Novak & Cañas, 2008) and "significant" (Fink, 2003) learning opportunities, and provide empowering learning experiences for the students (Preszler, 2004; Morse & Jutras, 2008).

2 Description of my CMaps Courses

The two upper-level undergraduate CMaps courses I implemented in the 2006-2007 academic year were Animal Behavior (for which 3 students were enrolled) and Ecology (for which 13 students were enrolled). The entire semester of Animal Behavior was a CMaps format, and first ½ semester of Ecology was a CMaps format. The second ½ semester of Ecology (taught by another professor) was a Traditional Lecture (TL) format. In my CMaps courses students work collaboratively in teams of 2-3 to create a CMap (with a congruent written summary page and reference page) for each major theme addressed. Adding a written summary page: (i) encourages students to carefully examine and modify their CMap in order allow congruence between the CMap and summary page; (ii) allows students to convert their non-linear knowledge from their CMap to linear knowledge; (iii) clarifies the CMap for readers who are not familiar with their structure; and (iv) develops students' writing skills. Cognitive learning theory suggests that linking verbal and visual mental activity improves retrieval for both (Nesbit & Adesope 2006). The textbook and both primary and secondary scientific literature are used as source materials. Students construct CMaps electronically using CmapTools™ (http://cmap.ihmc.us) and/or Microsoft™ PowerPoint software tools.

For both Animal Behavior and Ecology, the topics covered are the same as those covered in previous non-CMaps iterations of the course. A topic takes approximately four 1-hour class meetings to complete, which is the same time needed for a topic in previous course formats. Students are required to bring an individual CMap (based on an assigned reading) to the first hour class meeting relating to a topic. During that class meeting students compare and discuss these individual CMaps in their small groups to reach a consensus CMap. In the second hour students revise the consensus CMap and start writing a summary page and reference page. In the third hour teams revise their CMap and summary to allow congruence between the two. In the fourth hour students complete their CMap and summary, evaluate themselves and their team members, and orally present their group's CMap. Team revision of CMaps facilitates learning (Morse & Jutras, 2008) and presentation of group CMaps to the class facilitates awareness of different perspectives and receptivity to new ideas (Angelo & Cross, 1993). As instructor, I oversee the teams' interactions and progress, congruence of each group's CMap to its group's summary page, and address confusions that arise.

In order to align assessment (Biggs, 1999; Fink, 2003) with the constructivist CMaps learning format, I score each group's CMap based on (i) complexity (relating to concepts, hierarchy levels, and propositions / linkages); (ii) congruence between the CMap and written summary; and (iii) completeness of the reference page. Additionally, students receive participation scores from me, their peers, and themselves. I never lecture in these courses; therefore, I never use exams to assess learning. Students in Ecology do receive an exam on material presented in the second half of the semester which is conducted in the TL format and which is taught by another professor. These courses each have weekly 3-5 hour field/lab experiences associated with them and grades relating to these are incorporated into each student's final grade.

3 Assessment of the Efficacy of my CMaps Courses

3.1 Triangulation of Assessment of my CMaps Courses

I collected data on the efficacy of my CMaps courses (compared to TL courses) by using three (one knowledge and two attitudinal) assessments. I collected data in the Spring 2007 Ecology (but not Fall 2006 Animal Behavior) course that allowed me to assess students' knowledge progression and CMap building skills over the semester. The first CMap that was assigned (after a CMap modeling session) was "What is Ecology?" for which the source material was the first chapter in the textbook. At the end of the semester, the students revisited this CMap and modified it to reflect what they had learned over the ½ semester of the CMaps course. The second assessment was an attitudinal survey students completed at the end of the semester for Animal Behavior (or ½ semester for Ecology). For the third assessment, I asked students to construct two CMaps (with a written summary page and reference to Novak 1998) that compared my CMaps course with TL courses. Students were required to use Novak's (1998) "5 Elements of Teaching" CMap as a template and asked to show emphasis of concepts by either enlarging and/or changing the color of the concept boxes, or by changing font characteristics of the concept words. Students were not restricted in the number of concepts they could emphasize; therefore, they were free to emphasize as many (or few) concepts as they wished. This attitudinal assessment was also completed at the end of the semester for Animal Behavior (or ½ semester for Ecology). Conclusions regarding the efficacy of my CMaps courses are robust due to the triangulation of assessment.

3.2 Assessment #1: The Development of a Knowledge Base and CMap Building Skills

3.2.1 Specific Methods of Data Collection and Analysis

The data that address the development of a knowledge base and CMap building skills were generated by comparing 5 Ecology groups' final (end of semester) "What is Ecology?" CMap with their first (beginning of semester) "What is Ecology?" CMap. These were assessed using Novak's & Gowin's (1984) criteria and Cañas *et al*. (2006b) taxonomy. No statistical analysis was conducted on these data.

3.3 Hypothesis and Results

Hypothesis: Student groups will show marked improvement in their final "What is Ecology?" CMap as compared to their first "What is Ecology?" CMap. This improvement will occur in the number of valid hierarchical levels and propositions that link concepts. Improvement may not occur in the valid number of cross linkages between concepts in different areas of the CMap because I did not emphasize this element when modeling CMap construction.

Results: All five groups' final CMap was more complex than their first CMap when scored using Novak's & Gowin's (1984) criteria. The mean increase in the total score was 48.30 (s.d. 47.28). The mean (and s.d.) increase in number of valid: (i) hierarchy levels was 2.50 (2.06); (ii) propositions was 23.80 (25.56); and (iii) cross linkages was 1.20 (+/- 1.30). The mean total score (and s.d.) for the final "What is Ecology?" CMap was 123.30 (50.37). The mean (and s.d.) of the other variables in this final CMap was: 8.30 (3.03) (hierarchy levels); 49.80 (25.47) (propositions); and 3.20 (2.59) (cross linkages). Using the Cañas et al. (2006) taxonomy with six topological levels of increasing complexity, two of the five groups' final CMap was at a higher taxonomic level than their first CMap. Three groups' first and final CMaps were at the same level, with one group's at each of the following three Levels: 4, 5, and 6 (the highest level, and therefore could not improve). The mean (and s.d.) increase of all five groups' CMaps was 0.40 (0.55) levels, from a mean (and s.d.) level of 5.00 (0.71; range: 4-6) to a mean (and s.d.) level of 5.40 (0.89; range: 4-6). The large variability in the data was due to the different creative structures of the CMaps; some were organized as classic top-down hierarchies, but others were organized as "wagon wheels" with radial spokes emerging from a central node. One groups' first map was so detailed and had seven cross linkages; therefore, it was difficult to improve upon. The CMaps generated by a group using CmapTools™ were consistently more complex than most other groups' maps generated using Microsoft™ PowerPoint. It is impossible to determine whether the effect is due to group membership, the software tool, or an interaction of these variables.

3.3.1 Discussion

It would be unusual for students to delete concepts from their first "What is Ecology?" map when generating their final "What is Ecology?" map; therefore, it is not surprising that the final concept map is more complex than the first. Nonetheless, the magnitude of increase in the mean (Novak & Gowin, 1984) CMap score, number of hierarchy levels, and number of propositions in the final CMap shows an increase in knowledge and an improved ability to construct CMaps over the ½ semester. These results are consistent with other CMap studies (see CMC 2004 & 2006 proceedings archived at http://cmc.ihmc.us Cañas *et al.*, 2004, Cañas & Novak 2006a; Preszler, 2004; Nesbit & Adesope, 2006). It would be disappointing if, after seven weeks of constructing CMaps, students did not improve their ability to construct CMaps.

3.4 Assessment #2: Students' Perceptions of My CMaps Course Compared to TL Courses Based on an Attitudinal Survey

3.4.1 Specific Methods of Data Collection and Analysis

These data were generated from the responses of the 16 students to an attitudinal survey completed at the end of the semester for Animal Behavior (or ½ semester for Ecology). The response to survey questions for which five response categories exist could not be statistically analyzed due to the small sample size (N = 16). The minimum sample size to analyze these questions is 25 (due to a minimum expected frequency = 5 for all categories). The response to other survey questions could be statistically analyzed because either fewer response categories were offered, or I was able to combine similar response categories to allow fewer than five categories. I determined the expected frequency of the combined categories based on the frequency that these categories were offered in the original survey. These data were statistically analyzed using chi-square (X^2) one-sample test for goodness of fit (Ambrose et al., 2007).

3.4.2 Hypotheses and Results

Hypothesis 1: Students will perceive that construction of CMaps facilitates their understanding of course material.

Results: All 16 students responded that CMaps were either "very helpful" or "helpful". While this result is unequivocal, these data cannot be statistically analyzed using chi-squared (X^2) one-sample test for goodness of fit test until 25 students are surveyed because five response categories were offered in the original survey (see minimum expected value = 5 criterion for chi-squared test; Ambrose et al., 2007).

Hypothesis 2: Students will perceive that construction of CMaps allows them to learn more material from the textbook and scientific literature than traditional classroom techniques (lecture and class discussion, respectively).

Results: The trend of the data differ according to context. Students responded that construction of CMaps was superior to traditional classroom techniques for learning scientific literature but not for learning textbook material. When asked about learning from the textbook, 7 of the 16 students stated CMaps and TL format were equal to each other. Another 7 students found construction of CMaps to be superior to TL, and only 2 found CMaps to be inferior to TL. Therefore, there was not a majority of students who perceived construction of CMaps to be superior to TL when learning textbook material. However, a majority (13 students) responded that construction of CMaps allowed them to learn much more ($N = 8$) or more ($N = 5$) than a guided class discussion of scientific literature. Only one student responded that CMaps and discussion provided an equal learning experience, and 2 students responded that construction of CMaps allowed less learning than a class discussion. The sample size ($N = 16$) was too small to permit statistical analysis.

Hypothesis 3: Students will perceive that construction of CMaps allows them to develop thinking skills more than traditional classroom techniques (lecture and class discussion).

Results: The trend of the data support this hypothesis. Twelve students responded that construction of CMaps developed their thinking skills much more ($N = 6$) or more ($N = 6$) than traditional classroom techniques. Four students responded that the two formats allowed for similar development. The sample size ($N = 16$) was too small to permit statistical analysis.

Hypothesis 4: Students will prefer the course be structured in the CMaps format over either a hybrid CMaps & lecture format or a lecture only format.

Results: The students showed a statistically significant preference for exclusive CMaps format over either other format. Twelve students preferred exclusive CMaps format, and four preferred a hybrid CMaps/Lecture format. The original survey offered 3 categories, therefore statistical analysis could be conducted with an $N = 16$ ($p < 0.001$; chi-squared (X^2) one-sample test for goodness of fit; expected value for each category = 5.33).

Hypothesis 5: Students will envision transferring their ability to construct CMaps to other courses or environments.

Results: A statistically significant number of students (14) responded that they envisioned constructing CMaps for other courses or readings, while only 2 students responded that they did not envision constructing CMaps ($p < 0.05$; chi-squared, X^2, one-sample test for goodness of fit; two categories: "transference" vs. "no transference"; transference expected value = 9.6 because three response categories were collapsed; no transference expected value = 6.4 because two response categories were collapsed). The two Ecology students who did not envision using CMaps in the future responded that they did see their value. In reviewing these students' responses to other survey questions, one student responded that CMaps and TL allow equal learning of the textbook, but that CMaps allowed much more learning than class discussions of scientific literature, and the two formats (CMaps vs TL and class discussion) allow equal development of thinking skills. The second student consistently responded with the most favorable CMaps response category for all questions except the transference question. Both students responded that they preferred the course continue as exclusively CMaps.

3.4.3 Discussion

3.4.3.1 Context-Dependence of the Perceived Usefulness of CMaps

While it is encouraging that students recognize that construction of CMaps is helpful in understanding material, results of the survey suggest there is a context-dependence to the perceived usefulness of CMaps. Students perceived CMaps as a better learning tool than class discussions of scientific literature, but only an equally useful learning tool as a TL for understanding textbook material. Below I propose two hypotheses (that are not mutually exclusive) to explain this context-dependent view.

Hypothesis 1: "Discomfort with Constructing CMaps in Perceived Unequivocal Contexts"

Students may view the textbook as a source of material that provides answers, and should not be questioned, challenged, or open to multiple interpretations. Therefore, students are uncomfortable when asked to construct their own knowledge from this source material, because they view that the knowledge has already been constructed for them, and they need only assimilate it. In this manner students are neophobic; they are afraid of their new role in which they are expected to question the authority of the textbook and synthesize their own understanding from it. Students may view scientific literature as material for which construction of CMaps is appropriate because scientific data and literature, by nature, are open to multiple interpretations. Students provided no written comments to either support or refute this hypothesis. In order to overcome students' discomfort with CMaps in perceived unequivocal contexts, students need to be convinced that textbooks are not unequivocal sources of knowledge. It is imperative that students be exposed to teachers who remind them that: (i) scientific textbooks are equivocal sources; (ii) most of the information provided within them is a result of the scientific method and is a basic summary of scientific literature; and (iii) this information will be outdated within a decade of publication. Therefore, students need to realize that textbooks should be open to inquiry and multiple interpretations in a manner similar to scientific literature. Students need to be exposed to this perspective from multiple teachers vertically throughout their educational progression. If students are not reminded of the equivocal nature of textbooks they will continue to believe that these sources provide information that should not be questioned and will continue to be resistant to active learning / guided inquiry methods of learning from textbooks.

Hypothesis 2: "More is Better"

Students may also perceive that a large volume of class notes is better than high quality class notes. Upon leaving a TL class meeting, and by extension a TL course, students have many pages of notes that they may perceive as being equivalent to lots of knowledge. Upon leaving my CMaps class meeting, student groups leave with 1-3 pages of dense (often confusing) material which is not fully clarified until the final CMap for the topic is completed. At the end of the semester, students have a portfolio of their groups' CMaps, but possess relatively few pages to show for their work. Students may be conditioned to believe "more is better", and may perceive that a CMaps course has short-changed their learning because an expert teacher has not lectured and provided them with a notebook of information. Written comments (collected from both attitudinal surveys) provided by four students support this hypothesis. In order to overcome the perception that "more is better", students need to be exposed to teaching pedagogies that embrace the philosophy that "less is more" (see Brooks & Brooks, 1999, p. 49-50).

3.4.3.2 A Discussion of Other Encouraging Results from the Attitudinal Survey

It was encouraging that: (i) most students recognized the value of constructing CMaps in developing their thinking skills; (ii) a majority of students expect to transfer this learning skill to new environments; and (iii) most students preferred that I maintain CMaps as the organizing structure of these upper-level undergraduate courses. These results show that students are willing to adapt to novel learner-centered approaches and are open to the pedagogical advantages of these environments, despite their context-dependent view of the usefulness of CMaps. Bonwell and Eison (1991) summarize that: (i) students prefer active learning over lectures; (ii) active learning strategies promote learning equally well as lectures; and (iii) active learning develops students' thinking and writing skills better than traditional lectures. Barkley et al. (2005) provide a literature review that strongly supports collaborative learning environments. One of the many conclusions they present is that students who work collaboratively in small groups have more favorable attitudes towards learning than students working alone in traditional classrooms. The results I found are congruent with those summarized by Bonwell and Eison (1991) and Barkley et al. (2005). Additionally, one of the key philosophies provided by Novak & Gowin (1984) and reiterated by Novak (1998) is that a positive learning experience is a key element to empowering learners.

3.5 Assessment #3: Students' Perception about My CMaps Courses Compared to TL Courses (based on using Novak's "5 Elements of Teaching" CMap to compare elements emphasized in each of the two course formats).

3.5.1 Specific Methods of Data Collection and Analysis

These data were generated from the response of 13 of the 16 students. Three students did not complete this survey. The 13 students who completed the survey individually constructed two "5 Elements of Teaching" CMaps that compared the two course formats (CMaps vs. TL). I generated a composite CMap for each of the two formats in which I tallied the number of students who emphasized each of 10 concepts Novak (1998) presents in his "5 Elements of Teaching" CMap. I did not include Novak's concept with the phrase "5 elements of teaching" because each of the five elements ("teacher"; "learner"; "knowledge": "evaluate"; "context") is illustrated as its own concept. Also, no student emphasized the "5 Elements of Teaching" concept when summarizing either of the two course formats. The additional 5 concepts represented in Novak's "5 Elements of Teaching" CMap that summarize the education process are: "educating"; "interact"; "the meaning of experience"; "disempowering"; and "empowering". The two composite CMaps (summarizing students' perceptions of the CMaps course format vs. TL course format) were compared statistically using chi-square (X^2) test of independence between two samples (Ambrose et al., 2007) to determine if different concepts / elements were emphasized in these two course formats. Additionally, each composite CMap depicting each of the two formats was statistically analyzed to determine if the 10 concepts / elements were represented equally or unequally (chi-squared , X^2, one-sample test for goodness of fit; Ambrose et al., 2007).

3.5.2 Hypothesis and Results

Hypothesis: Students will perceive that the two course formats emphasize different suites of concepts, with an uneven distribution of these for both CMaps and TL course formats. Students will perceive that CMaps courses are empowering and provide an opportunity to interact; therefore, these concepts will be over-represented in the composite map. Concepts that will be under-represented will be "evaluate" and "disempowering". Students will perceive that TL courses emphasize the teacher and may be disempowering; therefore, these two concepts will be over-represented in the composite map. Concepts that will be under-represented will be "interact" and "empowering".

Results: The distribution of the concepts emphasized in the comparative (CMaps vs. TL course format) CMaps was statistically significantly different from each other ($p < 0.001$; d.f. = 9; chi-square, X^2, test of independence between two samples; Ambrose et al., 2007). Students' perceptions of both types of course formats also showed an unequal distribution of emphasized concepts ($p < 0.001$; d.f. = 9; chi-square, X^2, one-sample test for goodness of fit; Ambrose et al., 2007). The total number of concepts emphasized by each student in their CMaps versus TL course format maps was not statistically different (sign test; Ambrose et al., 2007; TL range: 2-7 concepts / student; mean = 5.00; s.d. = 1.35; CMap range: 2-7 concepts / students; mean = 5.15; s.d. = 1.41).

Concepts that students emphasized most strongly regarding my CMaps courses were (in descending order): "learner", "empowering", "interact", and "knowledge". Each of these concepts was strongly over-represented in the composite map; 12 (of the 13) students emphasized "learner", 11 "empowering", 10 "interact", and 9 "knowledge". Concepts that students chose least often to summarize my CMaps courses were (in ascending order): "disempowering"; "meaning of experience"; "teacher" and "evaluate". For example, only one student emphasized "disempowering" (and this student also selected "empowering", yet provided no written clarification regarding the ambiguity).

Concepts that students most strongly emphasized when summarizing TL courses were (in descending order): "teacher", "knowledge", and "disempowering". Each of these concepts was strongly over-represented in the composite map. For example, "teacher" was emphasized by 12 (of the 13) students, "knowledge" by 11 students, and "disempowering" by 10 students. Concepts that students chose least often to summarize TL courses were (in ascending order) were: "interact" and "meaning of experience", "learner" and "empowering". Only two of the 13 students emphasized "interact" and "meaning of experience", and only four emphasized "learner" and "empowering".

3.5.3 Discussion

My hypothesis regarding students' perceptions to my CMaps course and TL course formats was supported; students perceive courses conducted in these to formats as being very different from each other. Students clearly view my CMaps courses as empowering experiences for learners, allowing them opportunities to gain knowledge and interact with peers and the teacher. Students perceive TL courses as ones in which the teacher dominates and provides knowledge, but which can be disempowering (partly due to the lack of interaction). Both formats showed under-representation of the element "the meaning of the experience". This concept within Novak's "5 Elements of Teaching" CMap leads directly to "empowering" and "disempowering". Students probably selected the concepts "empowering" and/or "disempowering" over "the meaning of experience" because of the strong emotions associated with "empowering" and "disempowering".

4 Elevating Construction of Concept Maps to a Higher Level

A CMap that includes cross linkages shows that students are thinking deeply about relationships between concept clusters. These students are rewarded when their CMap is scored according to Novak's and Gowin's (1984) technique and Cañas *et al.* (2006) taxonomy. Additional components that could be added to concept maps to elevate students' cognitive processing include: (i) a written summary (with references); (ii) qualitative emphasis of components; and/or (iii) quantitative emphasis of components. I have described how I incorporate a written summary (with references) earlier in this paper. I have also described the manner in which I used a qualitative manipulation of Novak's "5 Elements of Teaching" to provide an assessment of my CMap courses. In a similar manner, students could alter components of their CMaps to emphasize specific concepts, linkages, or cross linkages that are particularly important. If the differences can be quantified, the numeric or probability value associated with the component could be placed within the concept enclosure or with the proposition (Porter 2008, personal communication, unreferenced). The qualitative and/or quantitative manipulation of the CMap may be relevant to some of the concept clusters but not to other clusters; therefore, this additional manipulation of the CMap need not be applied to the entire CMap. Scores for CMaps that include these added levels of complexity should reflect the deep thinking associated with these components. These enrichments of a CMap could be used as an additional challenge and motivator to students already proficient with the basic CMapping skills (possibly as a capstone CMap), or could be used when students work collaboratively on a CMap to promote deep and meaningful discussions of a topic / question about which students already perceive themselves as knowledgeable.

5 Summary

In this paper I describe the implementation of CMaps as the organizing structure in two upper-level undergraduate biology courses and demonstrate the efficacy of these CMaps courses using three (one knowledge and two attitudinal) assessments. Students constructed more complex CMaps as the semester progressed, and perceived my CMaps courses to be learner-centered empowering experiences that provided interaction as well as knowledge acquisition. Generally students favored my CMaps format over TL format, although there was a context-dependence to the perceived usefulness of CMaps. Students perceived constructing CMaps of scientific literature to be more useful than a class discussion, but perceived constructing CMaps to be only equally as useful as (but not superior to) a lecture for textbook material. Within this paper I propose two hypotheses to explain this context-dependence perception. Below I provide a summary CMap.

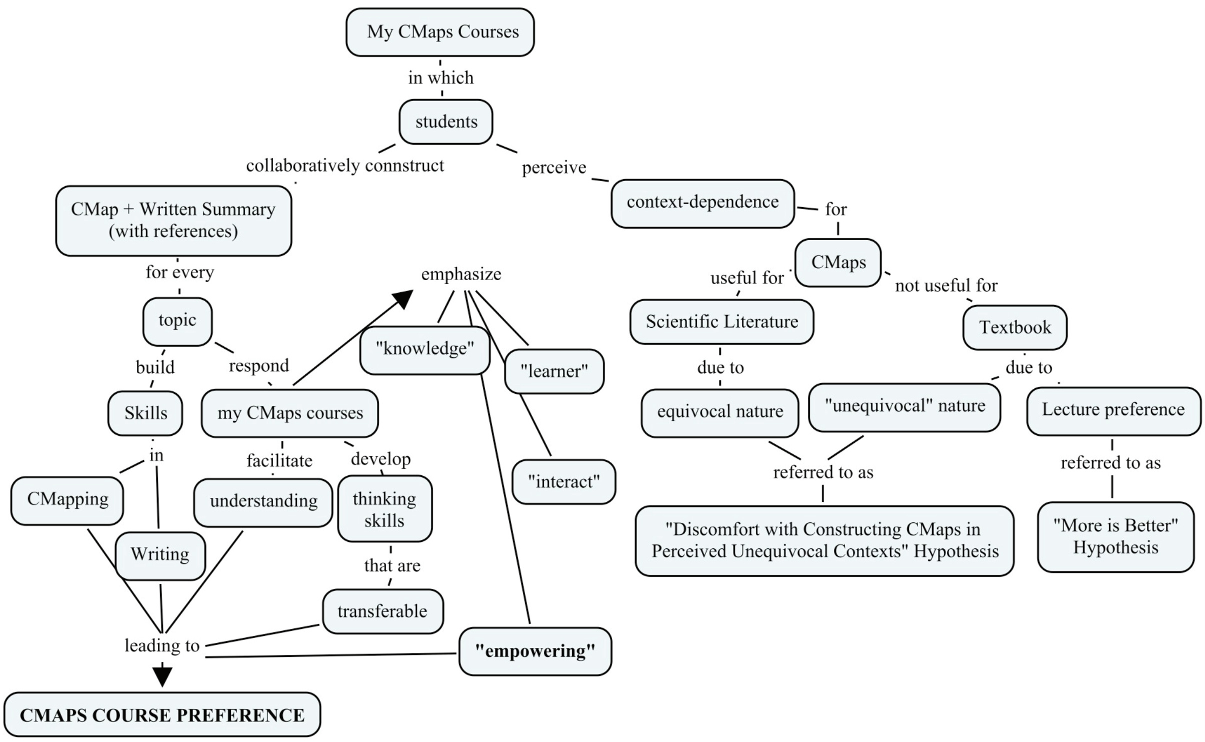

Figure 1. Summary concept map: CMaps as the organizing structure in my two upper-level undergraduate biology courses.

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quantitative component to CMaps. Anonymous reviewers provided insightful comments that I incorporated into this publication and the presentation of this paper at the CMC 2008 meeting.

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ADVANCING CONCEPT MAP RESEARCH: A REVIEW OF 2004 AND 2006 CMC RESEARCH

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Abstract. The purpose of this study was to conduct an integrative literature review of all papers and posters presented at the 2004 and 2006 Concept Mapping Conferences. In this review, 322 papers and posters, written in both English and Spanish, were reviewed. Six researchers reviewed the papers and created a matrix outlining each research study, the methods, the findings, and the implications. This matrix was then used to conduct a meta-analysis and identify six overall themes of research presented at the 2004 and 2006. These themes were identified as 1. teaching and learning, 2. assessment and scoring, 3. knowledge development, 4. software development, 5. professional development, and 6. research methods. In addition, researchers propose directions for future research in concept mapping.

1 Introduction

Concept maps were originally created at Cornell University as a research tool by Dr. Joseph Novak. Novak and his colleagues were conducting a 12 year longitudinal study on how children learn science concepts. In this study they created "28 lessons that dealt with the particulate nature of matter, energy types and energy transformations and energy utilization in living things" (Novak, 2004, p. 458). Children completed audio-tutorial lessons on these topics and then the research team interviewed these students about their learning. With hundreds of interview tapes to analyze, the research team began looking for alternative data analysis strategies. As Novak (2004) indicates, "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*" (p. 460). Novak and colleagues continued to research and teach with concept maps over the years and eventually initiated a partnership with the Institute for Human and Machine Cognition (IHMC). IHMC developed CmapTools, a software program for creating computer generated concept maps. Over the last few years, IHMC has continued the development of CmapTools and facilitated the creation of the International Concept Mapping Conference (CMC), with the first conference being held in Pamplona, Spain in 2004 and the second conference being held in San Jose, Costa Rica in 2006.

As we approach the third concept mapping conference, we believe it is time to step back and analyze the work that has been done to date and articulate some possible directions for future research in concept mapping. The use of concept maps has grown and developed in teaching and learning, in research, in business, and in working with small groups to name but a few examples. But how is all this research linked together? Are there future directions that research in concept mapping needs to explore? What can we learn from previous research that informs our practice and our future studies? In this paper we pose the overall question: Can the research agenda in concept mapping be advanced by conducting a meta-analysis of conference proceedings from the 2004 and 2006 conference? The purpose of this paper is to report the results of a meta-analysis of all papers and posters in the previous CMC proceedings.

2 Research questions

The following research questions were advanced to guide this inquiry: 1. What types of research have been conducted at the 2004 and 2006 CMC conferences? 2. What overall research themes are represented at the conferences? 3. How do these research themes advance knowledge in the area of concept mapping? 4. What implications do the research papers and themes have for future work in the area of concept mapping?

3 Methodology

According to Creswell (2008), a thematic integrative literature review is one in which the researcher uses the literature to identify themes and patterns in areas of research, and then discusses those themes with general reference to the studies from which they came. Drawing from the conference web site and published proceedings, three English speaking and three Spanish/ English speaking researchers conducted a thematic literature review of the entire set of conference papers and posters from the 2004 and 2006 CMC conferences. The researchers reviewed 322 papers and posters in English or Spanish, and were unable to review only one submission, which was in a language other than English or Spanish that was not spoken by the researchers, The papers reviewed were from 38 different countries. During this review each researcher contributed to a matrix that specified the name of the paper, the authors, the language of the paper, the country(ies) of the researcher(s), the year of publication, a short summary of the article, the methods, the findings, and the implications for practice and research. From this matrix initial themes were identified that represented the major research categories and topics presented at the CMC conference. The researchers then met to discuss, refine, and modify the initial themes created and to agree on the final list of six themes. A concept map (Figure 1) was created identifying these major themes.

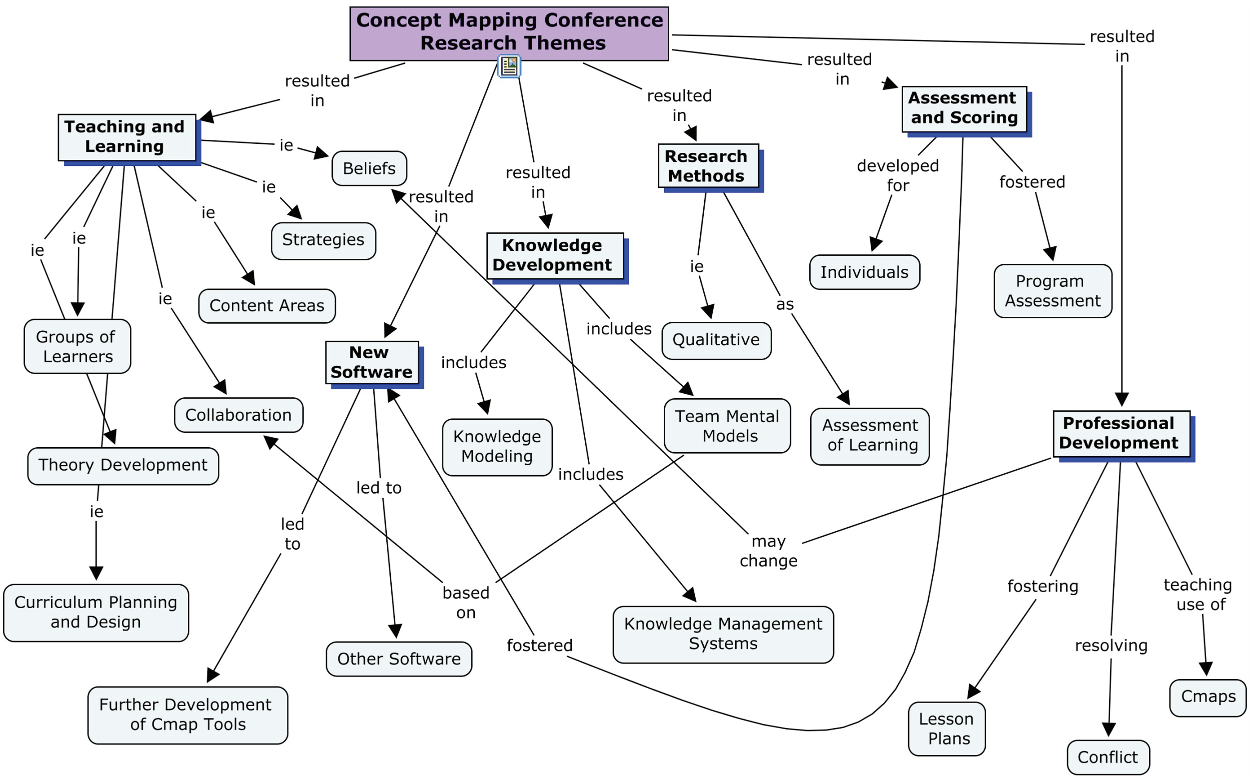

Figure 1: Concept Map of Research Themes Identified in CMC 2004/2006

4 Research themes identified

According to Mandl and Fischer (2000) 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 modeling" (as cited in Fourie & Schilawa, 2004, p.250). Based on our review of the CMC conference proceedings, it is evident that the use of concept maps has expanded into many other areas as well. As shown in Figure 1, we identified the following areas where concept mapping was being investigated in the CMC 2004 and 2006 conferences: teaching and learning, assessment and scoring, knowledge development, creation and expansion of software, research methods, and professional development. Each of these areas is discussed briefly in the next section of this paper.

4.1 Teaching and Learning

The theme that generated the largest number of papers was on the application of concept maps as a teaching and learning tool and the presentation of innovative ways of using concept maps. For student learning, concept maps have been used as advance organizers (Nathan & Kozminsky, 2004; Tavares, 2004), for educational group activities (Rojas-Drummond & Anzures, 2006), to produce a virtual magazine (Vargas, 2004), to improve reading and comprehension (Aránguiz, Berraondo, & Torre, 2004), to teach math (Edurne, Arantza, & Fermin, 2006; Olivares, 2006; Bolte, 2006), as a research tool (Åhlberg, 2004), as part of sharing teaching experiences (Ramos, 2004), as a self-reflection and self-regulation tool (Hugo & Chrobak, 2004), and to do research and complete literature reviews (Tysick, 2004).

4.1.1 Instructional Strategies

For instructors, concept maps have been used as a tool to organize instruction and to gather student feedback on learning (Fonseca, Extremina, & Fonseca, 2004), to assess student word problems through action research (Prabhu, Elmesky, & Czarnocha, 2006), to prepare teachers through portfolios and course planning (Iuli, Wagle, & Voetterl, 2006), and to assess understanding of science concepts and science language production (Stoddart, 2006). Papers also described innovative methods for using concept maps: pictorial concept maps (non-hierarchical and with limited linking words) to provide medication instructions for patients who have chronic diseases and low literacy (Hill, 2006), crossword puzzles and concept mapping (Tifi, 2004), construction of relevant terms for googling using a concept map and keywords generated from main concepts (Cañas, Carvalho, Arguedas, & Eskridge, 2004), and creation of maps with aluminum foil as the connections promoted creativity (Lombardi & Tifi, 2004).

4.1.2 Beliefs

A few conference papers focused on teacher beliefs. Mellado, Silva, and Ruiz (2004) wrote about their use of concept maps on interviews as instruments of analysis of high school science teachers' understandings about their own teaching. Banet, Sánchez, and Valcárcel (2004) used concept maps for analysis and reflection of university teaching in order to identify the teaching characteristics and to allow instructors to critically analyze their own teaching practice. González, Bermejo, and Mellado (2004) described a longitudinal study comparing a high school biology teacher's thinking about teaching and learning through a questionnaire and concept map analysis.

4.1.3 Content Areas

Papers focused on research on teaching and learning related to a variety of content areas. Some of the content areas included engineering (Feregrino-Hernández, Reza-García, Ortiz-Esquivel, Navarro-Clemente, & Domínguez-Pérez, 2006; Cálad, 2004), math (Heinze-Fry, 2004; Oneca, Sanzol, & Poveda, 2006; Vagliardo, 2004), physics (Alias & Tukiran, 2006; Valadares, Fonseca, & Soares, 2004); medical education (Illas, 2006), photography (Gimena, 2004), writing (Straubel, 2006), and pharmacy (Hill, 2006).

4.1.4 Groups of Learners

Papers were written based on the study of different groups of learners ranging from kindergarten (Mancinelli, 2006), elementary (Venditti & Sabba, 2006; Aquilino & Patrizia Venditti, 2006), middle, and high school learners (Pantò, Tifi, Trinchero, Vayola, & Zucchini, 2004), undergraduate and graduate students, medical students, and business learners (Bowen, 2006).

4.1.5 Theory Development

Some of the conference papers focused on theory development or analysis of existing theories in the use of concept maps and Vee diagrams. For example, Tamayo and Arroyo (2004) contended that concept maps are symbolic systems that represent a narrative and, therefore, can be interpreted. Tamayo (2004) states that reading a concept map is not only a representation of a text, but also the text itself with cultural and symbolic characteristics. In 2006, Tamayo presented a theoretical paper addressing the concept of immediate development zone by Novak as guiding the learning process and connecting concept maps within Vygotsky's social cultural theory. Several papers stressed the application of Reigeluth Elaboration Theory on the use of concept maps (Pérez, Suero, Montanero, & Pardo, 2004; Murillo, Zamora, Martínez, Alcalde, & Ballester, 2004; Solano, Pérez, & Suero, 2004; Pérez, Suero, Montanero, & Pardo, 2004). Kankkunen (2004) attempted to link Peirce's semiotic paradigm and concept mapping as a way to explain different levels of reasoning.

4.1.6 Collaboration

Collaboration has been a strong theme within the different papers for both conferences. Some papers suggested new methods for doing collaboration; others suggested new ways of looking at collaborations. Tifi and Lombardi (2006) described the WWMAPS, a community of education through collaborative concept mapping for primary and secondary schools across cultures to enhance multi-lingual skills. Lehmuskallio (2006) proposed a global information system called NatureGate which uses concept maps to explain ecological, economical, and social sustainable development. Khamesan and Hammond (2004) looked at synchronous collaborative concept mapping via text and text/audio enhancement with computers. Berionni and Baldón (2006) described how teachers in Italy launched an innovative project about community building across ages and cultures in science teaching with students 6-13 years old. Rodríguez, López; Fernández, and Montanero (2006) showed the process of collaborative reconstruction of concept maps with future physics teachers.

Gustavigna et al. (2004) described the development of a community of practice of concept mapping in Italy. The community aimed at structuring and organizing selective criteria in order to produce and make available documentation.

4.1.7 Curriculum Planning and Design

Concept maps have been utilized to plan and design curriculum using a variety of strategies. Vilela, Austrilino, and Costa (2004) used concept maps as a curriculum development tool by having a group of curriculum developers identify missing linkages, inconsistencies, false assumptions, and unrecognized relationships. Cantú, Farines, and Angotti (2004) described the use of concept maps to generate a thematic approach to organizing curricula. Colli, Rossi, Giordani, and Carla Montagna (2004) described methods instructors used to organize their curriculum using CmapTools to examine and explain ideas. Cabral, Zeve, Nicolao, and Amoretti (2004) described a method of using concept maps to organize web pages for distance learning courses. With the purpose of identifying major curricular issues in a graduate program in Turkey, Paykoç, Mengi, Kamay, Önkol, Özgür, Pilli, and Şahinkayası (2004) described the use of a mind mapping process to brainstorm key issues and to evaluate the program. Bueno and García (2004) utilized document analysis through concept maps to compare methods used to determine the profile of the curriculum in the area of science in secondary education. Riveros, Castro, and Gutiérrez (2006) used concept maps to formulate, update, plan, and follow-up on an engineering curriculum program.

4.2 Assessment and Scoring

The second theme identified in this literature review was assessment and scoring. Concept map research was being conducted on how to score the maps of individual learners and how to use maps in the assessment of programs.

Numerous authors discussed the development of formulas for scoring individual maps. Yao, Yang, and Zhao (2006), for example, proposed an algorithm based on scoring the propositional chains in concept maps. In this method of scoring the relationships between groups of propositions is demonstrated. Takeya, Sasaki, Nagaoka & Yonezawa (2004) developed a formula to compare student maps to maps of teachers. Mls (2006) proposed scoring maps based on the spatial relationships in the maps. Mls developed a formula to measure the spatial distance between concepts, and hypothesized that the greater the distance between concepts the less the learner actually understood about that concept. In contrast, Ruiz-Primo (2004) proposed that to use concept maps as an individual assessment tool requires that the assessment be based on the task to be mapped, the response format required by the instructor, and the scoring system. Ruiz-Primo advocates that the degree of directedness of the maps needs to be considered in the assessment. By this she means was there high direction in the mapping task (fill in the blank maps) or low direction (maps totally constructed by learners). Finally, Khamesan and Hammond (2004) move the understanding of scoring maps forward by proposing three levels of measuring learning effectiveness with concept maps: individual learning, whole group learning, and interaction between the group and the individual. They propose a taxonomy in scoring that differentiates which concepts were created at the individual level, from new concepts that were created at the group level. They also propose a method to analyze which concepts were transfer or rejected between the individual and the group. This work supports efforts to understand how learning differs at the individual and group level.

In addition, concept maps were used to provide program assessment. In these studies, maps were used to analyze what concepts were being taught and how those concepts were being evaluated. In some papers authors discussed how concept maps were used to align curriculum with state standards. Heinze-Fry and Ludwig (2006) used concept maps to align a public school elementary life science program within the framework from the state. They designed a template concept map to demonstrate where the local program fit with the state standards. Similarly, Carnot, Gaudet, and Hinesley (2006) used concept maps in a psychology program to prepare for an accreditation visit by linking course learning goals and program goals. Additionally, the CmapTools software capability for resource files to be linked to maps is expected to be useful in this process as well.

4.3 Knowledge Development

Knowledge development was the third area where concept map research was conducted in the 2004 and 2006 conferences. The broad category of knowledge development includes knowledge modeling, knowledge elicitation, knowledge recovery, the development of team mental models and the development of knowledge management systems. Concept maps have been used in all of these areas to significantly advance our understanding of how knowledge develops within individuals, groups and organizations. In the areas of knowledge elicitation and knowledge recovery, Coffey, Eskridge, and Sanchez (2004) describe how concept maps were used to elicit knowledge for the preservation of institutional memory in the nuclear power industry. Coffey (2006) then goes on to describe techniques for the creation of concept maps with a subject matter expert and a concept map facilitator. Beuter and Pinto (2004) also provide samples of knowledge elicitation techniques that can be selected based on the type of knowledge to be elicited, the software available, the sophistication of the client, and the type of problem for which knowledge is generated. Hoffman and Eccles (2004) report on the development of a large knowledge model made up of over 150 concept maps. They indicate that the process of knowledge recovery is very costly when considering the time and effort needed to create knowledge models. They suggest that organizations make knowledge capture an on-going part of their work rather then trying to elicit and recapture knowledge at a later date. In contrast to these authors, Freeman (2004) in a study comparing three treatment groups of analysts and users working together found that concept maps did not assist the analyst during requirements elicitation. Freeman's findings are in stark contrast to other researchers working in this area and he suggests that additional studies need to be conducted to determine if concept mapping and requirements elicitation can be combined effectively.

Concept maps have also been incorporated into the study and development of team mental models. Evans, Harper, and Jentsch (2004) hypothesized that teams exhibiting both high levels of expert knowledge and familiarity with teammates would perform at higher levels. Bowen and Mayer (2006) described how concept maps were used with a newly formed Board of Directors to create shared vision, map core values, and to develop a governance structure. Basque and Pudelko's (2004) research examined the effect of dyads developing knowledge models. They found a tendency that working at a distance in a synchronous fashion was beneficial to the development of team mental models. Keller and Tergan (2006) found that computer-supported collaborative learning, using the KIA-tool for concept mapping, lead to better collaboration and more efficient problem solving in groups. Johnson et al. (2006) compared four research methods for studying concept maps and the development of individual and group mental models. Their study found that various models are needed to understand the complexities of how team mental models develop.

Finally, concept maps have been used to develop knowledge management systems in organization such as banking (Fourie & Schilawa, 2004), the chocolate history project at University of California-Davis (Lange & Grivetti, 2006), and to develop an understanding of consumers branding knowledge (Reesink, 2004). According to Briggs, Shamma, Cañas, Carff, Scragle, and Novak (2004), concept maps can also be used to develop a library of concepts accessible to the general public. They describe the CMEX Mars indicating how concept maps were used to create a knowledge management system to describe all aspects of Mars exploration.

4.4 Software Development

Another theme that emerged from the conference papers is the development, testing, and application of software programs in different parts of the world. In Spain, the ARK.I.NET software was designed to allow users to collaboratively construct knowledge at the concept, theme, relation, and map levels (Madrazo & Vidal, 2004). In Norway, Cerpus AS developed Brainbank Learning, a web based application that represents a systematic way of constructing and documenting knowledge during the learning process (Salazar & Renauld, 2004). In Germany, computer-based concept map software was developed and applied to the subject of music (Weyde & Wissmann, 2004). In Greece, a web enabled concept mapping learning environment, Compass, was created to support multi-feedback forms and components adapted to learner's characteristics (Gouli, Tsakostas, & Grigoriadou, 2006).

In Chile, software was designed and re-designed according to teachers' pedagogical needs and to implicit cultural requirements of Chilean schools (Sánchez & Alarcón, 2004). In Argentina, Moroni and Señas (2006) proposed a new form of visualizing programs using Pascal Language in order to make information more meaningful for the viewer. In Costa Rica and Cuba, software programs were analyzed to review their advantages and disadvantages (Simón, Estrada, Rosete, & Lara, 2006). In Venezuela and Spain, ATLA/ti software was developed to construct concept maps to analyze the complexity of teaching math (Bencomo, Godino, & Wilhelmi, 2004). In Australia, Gomez (2006) developed a symbolic mapping apparatus for use in the early childhood classroom.

In the U.S., the software "counselor," using a case-based algorithm, was developed to offer suggestions for layout of concept maps (Brenes & Valerio, 2006). Luckie, Harrison, and Ebert-May (2004) described the concept map scoring software C-TOOLS, created to develop and validate a new assessment tool, the Concept Connector, consisting of a web-based concept mapping Java applet with automatic scoring and feedback functionality. Leake, Maguitman, and Reichherzer (2004) described the development of the CmapTools concept suggester, an effective tool in early concept mapping. Clariana and Koul (2004) explained the software tool called ALA Reader to translate short passages into maps.

4.5 Professional development

Concept maps have also been used in numerous countries to foster the professional development of teachers. The maps have been used to help teachers understand subject matter content and to assist teachers in focusing more on student learning. Maps were also used to assist in the development of lesson plans and to foster a deeper understanding of teacher beliefs. Studies also indicated that when teachers learned to use concept maps their teaching approaches and teaching beliefs changed. For example, Leou and Liu (2004) conducted an eight year case study of experiences of math teachers, finding that concept maps assisted the teacher to change from the deliverer of content into the communicator and distributor. In this study, math teaching changed and effectiveness increased as the participant gained more self-confidence. Bermejo (2004) used concept maps to assist teachers in developing their understanding of the philosophy of science. Conlon and Bird (2004) in a study in Scotland, found that concept mapping is not yet part of mainstream teaching practices, but they also found that most teachers regard mapping highly as a teaching technique. They conclude that with the right kind of support and increased staff development teachers can gain confidence to use mapping in their teaching and thus expand their teaching repertoire.

4.6 Research Methods

Finally, using concept maps as research tools was an area discussed by authors of CMC papers. It is interesting to note that Iuli and Helldén (2004) remind us that concept maps were originally developed as a data analysis tool to demonstrate how children's understanding of science grew and changed during a longitudinal study. Iuli and Helldén go on to describe four research studies in which they use concept maps as part of the methodology. They state, "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 university across the U.S." (p. 367). Additionally, Carnot (2006) describes the use of concept maps as a way to organize literature reviews for two large scale projects. Cahuzac and LeBlanc (2004) discuss how concept maps were used during an anthropological field study to explain mental representations of participants. Finally, Daley (2004) provides examples of how concept maps were used in qualitative research to frame research projects, reduce data, analyze themes, and present findings. She goes on to indicate that the advantage of using concept maps in qualitative research is linked to maintaining the meaning of the data in a unique context, but the disadvantage may be the complexity of the maps. What this work demonstrates is that concept maps have a role to play in both quantitative and qualitative research methods in a variety of disciplines.

5 Implications for Future Research

As demonstrated in this review, the research on concept mapping has expanded significantly with the advent of the International Concept Mapping Conferences. The CMC has provided an avenue for dissemination of concept mapping research from around the globe. Based on our review of the CMC proceedings and the themes identified in this paper, we envision a bright and exciting future for concept mapping research. It appears to us that additional research is needed in a number of areas. Based on our work here, we advocate that the next generation of concept mapping studies be designed to push the research forward into areas that have been neglected or under-explored.

First, it is well documented that concept maps are an effective instructional strategy across various ages of learners within a variety of disciplines. We know that concept maps support learning in both a cognitive and constructivist fashion. Additionally, we know that for concept maps to be used effectively teachers/faculty need to be able to shift their style of teaching and/or their beliefs about teaching and learning. What we do not fully understand, however, is the resistance to mapping on the part of some learners and some teachers. Does this resistance come from an inability to change learning and teaching strategies, or does this resistance emanate from innate learning styles? We also do not fully understand how concept mapping integrates with other thinking and learning processes such as deep learning processes, developing mental models, critical thinking, clinical reasoning, and diagnostic reasoning. Additionally, the field could benefit from research on how concept mapping can be used in on-line and hybrid course, as well as, how concept mapping may facilitate learning when paired with other technologies such as learning objects and PDAs.

Second, we suggest more research in the area of group learning with concept maps. Studies have shown that shared mental models can develop through collaborative learning and from the interaction of individuals in the development of a group map. However, the processes that groups use to build from individual maps to a group map need more investigation. Additionally, we need to understand more fully how teams and groups construct knowledge and then how that process of knowledge construction facilitates the performance of the group. When groups and teams develop a shared mental model with concept maps, how does their performance compare to groups who have not engaged in this process?

Third, our review indicates that one of the most neglected areas of research in concept mapping is in the conduct of longitudinal studies. Most of the studies with concept maps show that learners change over the short term, but other than Novak's (2004) original 12 year study there are very few longitudinal concept mapping studies. In this review one study (Daley, 2004) followed students for a year to assess their continued use of concept mapping, however, even this can be considered short term. Longitudinal studies of learning outcomes based on concept mapping are greatly needed across many disciplines and with a variety of learners.

Fourth, the use of the CmapTools software needs continued research. As this software continues to be developed the innovations that are added to the program need to be assessed and evaluated. For example, the effectiveness of the concept suggester and the Cmap recorder need further research. It would be most interesting to investigate if we can understand how a learner's thinking develops and/or changes by assessing each step in map construction through using the Cmap recorder.

Fifth, a neglected area of research seems to be in the connection of concept mapping and culturally relevant teaching and learning. There were a few studies in the conference proceedings that mentioned that maps could be used to build communities of diverse learners, but this was not really studied in depth by any of the researchers. It would be interesting to understand more about how different racial or ethnic groups use concept maps in their learning. Can our teaching be more relevant to diverse learners through the use of maps?

Sixth, in this review there was a beginning analysis of different ways maps can be used in assessments and there were a number of scoring formulas proposed for concept maps. This entire area of assessment and scoring needs much greater development. How can we use concept maps to assess and document learning and/or change in meaning and understanding for learners? This is crucial as there is a great deal of focus on learning assessment within all levels of education. Can a scoring method be developed that clearly documents learning outcomes?

Seventh, we need to continue investigating the use of concept maps as research tools in both quantitative and qualitative studies. We need validity and reliability testing of concept maps compared to other measures of learning. Additionally, we need assessment of maps and their potential to contribute to quality control in qualitative studies.

Finally, research in the areas of knowledge development, knowledge modeling, and knowledge systems need to be expanded, especially within a variety of organizations. We need research to help understand how concept maps can function in analysis of job tasks, foster institutional memory, support the development of expert knowledge, and analyze social relationships and group conflicts. This type of research has the potential to help our profit and non-profit organizations function at increasingly higher levels.

In conclusion, as Ausubel indicates, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teaching him accordingly" (as cited in Novak & Gowin, 1984, p. 40). As such our literature review is designed to document what we already know about the technique of concept mapping so that we can continue to move forward pushing our research and our own learning in new, uncharted directions.

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[reminder of references for this paper can be found at: http://www.uwm.edu/~bdaley]

AN APPROACH TO COMPARISON OF CONCEPT MAPS REPRESENTED BY GRAPHS

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Abstract. We present a proposal for automation of concept maps comparison for different applications, for instance, as a support for the teacher in the task of learning assessment. Graph matching is suitable to model the comparison of objects which can be represented by graphs. The approach is based on a Combinatorial Optimization formulation for graph matching and algorithms for its resolution. This work intends to adapt it for use in the recovery of intelligent information, namely, the comparison of concept maps in representation of knowledge, as well as investigate the use of heuristic algorithms for its resolution.

1 Introduction

Concept Maps (Novak, 1998; Novak & Cañas, 2006) have been used as a tool to support the representation of knowledge. With them, it is possible to show, organize and represent knowledge about a particular subject (Araújo et al., 2002). Concept maps have been used by students to describe their understanding of a particular piece of reality. In the learning process, in examining concept maps constructed by apprentices, it is possible to identify what has been learned and the difficulties encountered, or even find concepts which are not yet understood and, therefore, need to be better dealt with. This analysis, however, can be very costly when it is necessary to review the various maps constructed by several apprentices on the same subject. The automatic identification of similarities between different maps becomes valuable in the activities of the teacher. In this task the computer can be placed as a major ally of the teacher, automating the identification of important aspects of the maps constructed.

We present a proposal for automation of concept maps comparison for different applications, for instance, as a support for the teacher in the task of learning assessment. The approach is based on a Combinatorial Optimization formulation for graph matching and algorithms for its resolution, proposed in (Boeres, 2002; Sarmento, 2005). In the next sections are presented briefly, a general proposal for concept maps comparison and its motivation (Section 2). The graph matching problem is discussed in Section 3 and an instance of the proposal using graph matching is presented in Section 4. Section 5 shows tools to construct data input for this problem, the algorithm used for its resolution and computational results. Conclusions and future work are in Section 6.

2 Comparing concept maps

Concept maps (Novak & Cañas, 2006) can be used to support knowledge representation and organization. According to Piaget, a concept results from a change in a scheme of action, in a process of endless juxtaposition of attributes by successive adjustments caused by disequilibrium (or imbalances) in the systems of signification of the subject. Thus, the words we put in the boxes of the maps (usually a noun) are not necessarily, in the view of the subject, the concepts. Even though such words may represent them, they are in fact delimited by the relationships created in the exercise of allocating meanings that are only achieved by the interaction of the subject with objects, in certain contexts. Therefore, it is opposed to the vision of a sequential and hierarchical mental structure built during a learning process (Fagundes, Dutra & Cañas, 2004). Safayeni also advocates that the cyclical concept maps, that is, not hierarchical maps, can be more effective for a more dynamic knowledge representation, allowing a greater possibility of a concept map configurations, both in its topology as in its type of connecting sentences (Safayeni et al, 2003). The addition of these two concepts is the notion of concept maps adopted in this article.

Concept maps are popular today and they are used to support different activities where knowledge needs to be organized and represented (Gava et al., 2003), notably in education (Dutra et al., 2004). In human activities we are taken by the curiosity to know their similarities and/or differences, and also to compare them. But, in addition to satisfy our curiosity, the comparison of concept maps may have other uses, as we can see in the following examples:

- A teacher asks his students to build, individually, concept maps on a particular issue and compare them to identify existing differences and similarities;

- A knowledge engineer calls for different experts to build concept maps describing the knowledge they have on a particular subject, such as "Mars". The comparison between them will allow to obtain a more precise description of the subject in question;
- Different texts can be described by means of concept maps. The comparison between these maps will allow knowing the degree of similarity between the different texts.

We can mention a simpler problem: given two concept maps, CM1 and CM2, what are the similarities between them? The treatment of the problem would be considerably simplified if the two maps were constructed using the same vocabulary and naming the concepts and relationships in a non-ambiguous way. We could make a comparison of the two maps and count the number of overlapping concepts, the number of concepts that appear in CM1 and do not appear in CM2, and vice-versa. Similarly, we can proceed with the relationships. Yet some major questions now arise: (1) the position of the concepts and relations in the figures used to describe the maps (layout), and (2) lack of uniform nomenclature to define the concepts and relationships presented in the maps.

2.1 Using graphs to compare concept maps

In addition to its pictorial representation, a concept map has an underlying structure of connections between their concepts. Because of this, equivalence between concept maps and a mathematical structure called graph can be established. It is important to note that, by establishing this equivalence, the existing knowledge on graphs can be applied to compare concept maps. Our strategy is to address the problem of comparing concept maps to a known problem in graph theory literature: *the graph matching problem*. In Figure 1, two different graphical representations for a concept map with the same concept relationships are presented. It can be observed that concepts of the same nature are related in the same way in both, even if it is not evident from the graphical representations. For instance, the relations *whale may be animal*, from one of the maps and *whale may be creature*, of the other, have similar meaning. These similarities can be also observed for the concepts and the other relationships established in both maps. Similarly we can find maps where the description of the relationships between two concepts is made by different sentences. It is also possible that a map has less relationships that another map.

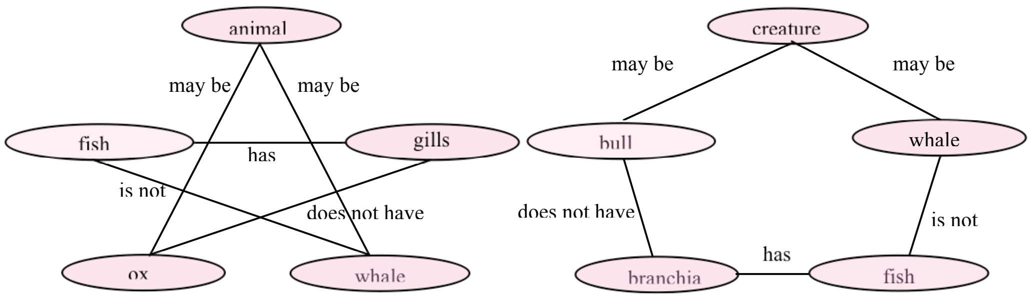

Figure 1. Two different graphical representations for the same concept map.

A graph G = (V, E) is defined as a pair of a set of vertices (or nodes) V and a set of edges E. The edges represent relationships between the vertices. They can be oriented or not, depending on the nature of relations represented. An attributed graph can have labels representing attributes to its nodes and edges, depending on the context of the problem modeled (Berge, 1983).

A concept map can be defined as an attributed graph G = (V, E) where the V set contains the nodes labeled by concepts and the E set contains the edges that represent every relationship between two concepts. The edges attributes can be words or phrases used to describe the relations between concepts. And, as the concept maps discussed in this work can be constructed with free vocabulary, different map constructors can use different words or phrases for a same concept and/or relationship. For example, in a statement talking about housing problems, a user can choose the word "house" and another, the word "dwelling" to talk about the same concept (housing). Thus, given two concept maps CM1 and CM2, the basic problem is to find a concept *e'* or a relation *r'* in CM2 that most closely matches a concept *e* or a relation *r* in CM1. This problem will be treated in this work using graph matching (Section 3).

The approach proposed in this work considers the comparison of two concept maps represented by attributed graphs. The maps comparison is performed using graph matching. For this, a semantic comparator is used to calculate the similarities among the concepts and relations, represented as attributes of both graphs. Thus, a solution to the graph matching problem represents an association between the concept maps compared. The whole scheme of this approach is presented in Figure 2.

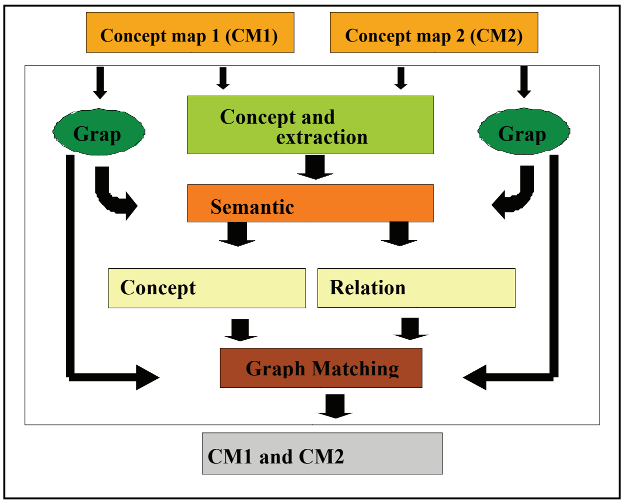

Figure 2. Schematic comparison of two maps.

3 The Graph Matching Problem

In the literature of graph theory one finds the problem of Graph and Subgraph Isomorphism formulated as a decision problem (Berge, 1983), that is, given two graphs, it is intended to identify the complete structure of a graph, or just a part of it, in the other graph. Motivated by image recognition applications, the graph matching problem is proposed in (Sarmento, 2005) as a combinatorial optimization formulation for the graph isomorphism problem (GIP). The GIP goal is to identify similarities between attributed graphs of the same size, considering their structures and attributes associated with their nodes and edges. Details of similarity, node to node and edge to edge of the two graphs, must be provided. This information can be calculated through metrics that consider cognitive data (the attributes associated with the graphs) and they must be stored in two matrices of similarity, one of them between nodes and the other between edges of the graphs compared. The formulation of the GIP as defined in (Sarmento, 2005) is reproduced below.

Let $G_1 = (N_1, E_1)$ and $G_2 = (N_2, E_2)$ be the compared graphs, with $|N_1| = |N_2|$ and $|E_1| = |E_2|$, and be still matrices with dimensions $|N_1|$ x $|N_2|$ and $|E_1|$ x $|E_2|$ of values in the range [0, 1], obtained from the graphs attributes, that represent respectively, the similarities between the nodes and edges of the two graphs. A solution to the GIP is a correlation X, between the nodes of G_1 and G_2, which maximizes the function

$$f(X) = \frac{\alpha}{|N_1| \cdot |N_2|} f^v + \frac{(1-\alpha)}{|E_1| \cdot |E_2|} f^a \text{ with } f^v = [\sum_{i \in N_1} \sum_{j \in N_2} (1 - |x_{ij} - s^v(i,j)|)] \text{ and}$$

$$f^a = [\sum_{(i,i') \in E_1} \sum_{(j,j') \in E_2} (1 - |\max\{x_{ij} \cdot x_{i'j'}, x_{ij'} \cdot x_{i'j}\} - s^a((i,i'),(j,j'))|)]$$

where α is a parameter used to weight each term of f. The first term on the right side of f represents the average contribution of the graph nodes associations for the matching, while the second term represents the average contribution of the graph edges associations. The value $s^v(i, j)$ (respectively $s^a((i, i'), (j, j'))$) is the similarity calculated from the attributes of the nodes $i \in N_1$ and $j \in N_2$ (respectively the edges $(i,i') \in E_1$ and $(j,j') \in E_2$). Restrictions have also been defined and imposed on the space of solutions in order to improve the search process of the best solution. The definition of these restrictions was based on the identification of characteristics of the problem treated and can be found in (Sarmento, 2005). A GIP feasible solution must satisfy the restrictions set imposed to the problem. The GIP formulation described in this section is used in this work to model the concept maps comparison problem.

4 Comparing concept maps using GIP

In this work, we address the problem of comparing concept maps to the GIP, described in Section 3. So, in this case, we consider that concept maps are treated as the graphs G_1 and G_2 and aim to find a solution to the GIP with the best value for the function *f*. In other words, we aim to find the solution that best represents the similarities of the two maps. We denote this problem as CMGIP. To solve the CMGIP, node and edge similarity matrices must be provided for the maps. In this approach, these matrices can be built from semantic algorithms as stemming and disambiguation algorithms.

The GIP, in its classical version, is *NP* (Fortin, 1996; Arvind, 2002). For this reason, approximate and exact algorithms are proposed for its solution, in several applications. As an example, in the literature of scene recognition based on this problem, there exists for its resolution, heuristic algorithms (genetic algorithms (Cross, 1997), neural networks (Buchanan & Shortliffe, 1984) and GRASP (Boeres, 2002; Sarmento, 2005)), probabilistic methods (Bengoetxea, 2002) as well as exact algorithms based on the branch-and-bound technique (Wong et al., 1990). In the approach proposed in this work, several algorithms for GIP resolution are suitable. We have adapted the heuristic GRASP proposed in (Boeres, 2002; Sarmento, 2005) for the CMGIP.

An instance of the approach scheme presented in Figure 2, considering the similarity matrices creation and algorithm for the CMGIP resolution, is showed in Figure 3. In this scheme, concepts maps CM1 and CM2 are represented as graphs G_1 and G_2 and their attributes (concepts and relations) are extracted and compared by a semantic comparator to construct the node and edge similarity matrices, needed to solve the CMGIP. Finally, a GIP algorithm is chosen to obtain a solution to the problem and have the concept maps compared, identifying their similarities.

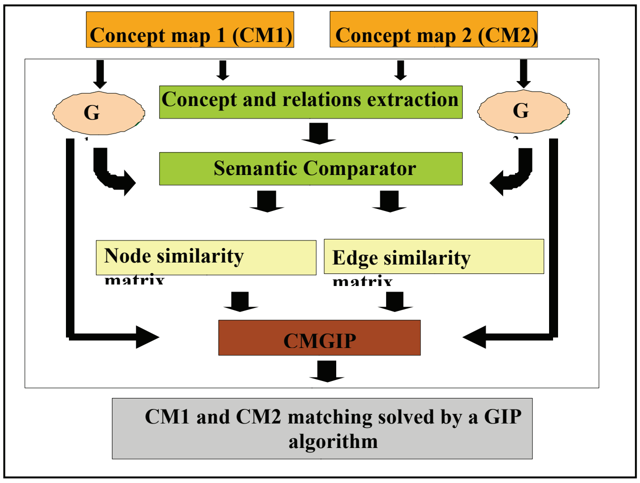

Figure 3. An instance of the approach proposed.

5 An instance of CMGIP

In order to evaluate the contributions of the approach proposed to the comparison of concept maps, an instance of CMGIP is described in this section. For this, in the next two subsections, the matrices creation and a CMGIP resolution algorithm are described further. Subsection 5.3 presents the results of the algorithm implementation for a specific set of concept maps.

5.1 Construction of similarity matrices from concepts and relations of two maps

The comparison of maps via CMGIP assumes the use of similarity matrices whose values are calculated from attributes associated to the graphs compared. In this approach, these attributes are concepts (for the nodes) and words or phrases, meaning concept relations (for the edges). For the matrices construction, it is necessary to quantify these similarities by means of numeric values. For this purpose, natural language processing algorithms were chosen: stemming algorithms (Rijsbergen, 1980), disambiguation (Gerrig & Lesk, 1990), and synonyms tree search algorithms created from WordNet (Fellbaum, 1998). These algorithms were implemented in this work from available versions for use on the Internet. However, they are restricted to the comparison of English language strings. Given two strings, these algorithms generate a numerical value (percentage), indicating how much two strings are semantically similar. In order to validate the use of these algorithms, the Microsoft Research Paraphrase Corpus tool (Quirk et al., 2004) was used to evaluate the quality of the comparisons made. It provides several pairs of sentences in English and their percentage of similarity, defined according to the assessment of two human judges. From the 5801 tests made we obtained 3909 hits, or 67% of fidelity in relation to the assessment made by the judges.

5.2 The algorithm GRASP used to solve the CMGIP (GCMGIP)

The metaheuristic GRASP (Greedy Randomized Adaptive Search Procedure) (Feo & Resende, 1995) is an improvement algorithm that generates good solutions (not necessarily the optimal solution) to a problem in a fairly processing time. This algorithm has been widely used in the resolution of combinatorial problems. It is an iterative algorithm with each iteration consisting of two phases: (1) construction of a feasible solution to the problem, and (2) its use as initial solution to a local search procedure. The solutions obtained at each GRASP iteration represent the exploitation of the search space by a local search from multiple starting points. The best among all the solutions obtained is the response of the algorithm.

The GRASP algorithm used in this work is that presented in (Sarmento, 2005): at each iteration of the algorithm, a solution is gradually built by elements chosen among candidates that do not violate the feasibility criteria established in GIP by the restrictions set defined. Then, this solution is used as a starting point for local search, performed in a neighborhood of solutions derived from the constructed one, from exchanges of associations established between nodes of the graphs compared. The parameters of the algorithm are: the graphs, the maximum number of iterations and an initial seed for the random number generator, used for the random selection of the elements that will compose the solution built. The algorithm ends with the best of the solutions obtained, after the execution of the maximum number of iterations. The GRASP algorithm pseudo-code is presented in Figure 4.

```
Input: G1 = (N1,E1), G2 = (N2,E2), Seed, MaxIter
i = 1
While i < MaxIter do
        Solution  = Construction-Procedure (Seed)
        Solution  = LocalSearch (Solution)
        i = i + 1
        UpdateSolution(Solution, BestSolution)
 End-While
Output: BestSolution
```

Figure 4. The GRASP algorithm

The input maps are easily represented by attributed graphs of the same size (G_1 and G_2) and their similarity matrices are created using the algorithms mentioned in Section 5.1. Considering the graphs and matrices, the GCMGIP algorithm construct an initial feasible solution (Construction Procedure) and starting on it, performs a local search in the problem solution space (Local Search), guided by the GIP objective function presented in Section 3. It returns the best solution found. As the GCMGIP is not an exact algorithm, the best solution obtained can be not the optimal one.

Maps of different sizes can be easily adapted to this algorithm by completing the lower graph with edges and nodes with null similarity values, so that their contribution are not considered in the values of the objective function, calculated for the solutions in the algorithm.

5.3 Experimental Results

Whereas we are working with heuristic algorithm, and as it is hard to estimate its complexity, we choose to make a preliminary performance evaluation in the resolution of specific situations. For the computational tests, nine pairs of attributed graphs were built from nine concept maps acquired in the Public CmapServers (Cañas et al. 2004). Four groups of these maps were organized for the algorithm executions: (1) The M0 group consists of pairs of identical maps, just to validate the algorithm, (2) The M1 group consists of pairs of maps with identical graphical representations but with some of the concepts replaced by close meanings or synonyms, (3) the M2 group consists of pairs of maps with different graphical representations but with similar concepts, and (4) the M3 group, consists on the union of M1 and M2 groups, with modifications imposed both on the graphical representations and on the concepts attributes of the maps. Even with the modifications imposed on the graphs, they should be identified as identical ones, because all pairs of graphs are isomorphic. For instance, Figure 4 shows an example of the M3 group. The underlying graphs of these concept maps are easily determined: each concept is defined to a graph node and each relationship between two concepts is defined to a graph edge. For instance, the concept relationship *exempli gratia*, in the left concept map of Figure 4 is converted to three different edges with the same attribute (*exempli gratia*), in its underlying graph.

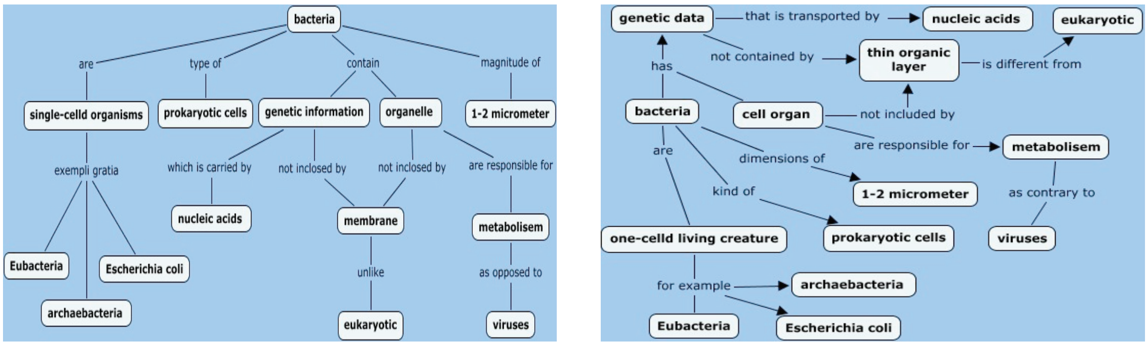

Figure 4. An instance of the M3 group.

Ten executions of the GCMGIP algorithm were carried out for each pair of maps of the groups M0, M1, M2 and M3. All tests were performed on an Athlon XP 2000+ computer with 768MB of RAM, operating system Windows XP SP2 and running code compiled into C# in Visual Studio 2005. Tables 1, 2 and 3 show the results obtained respectively for the groups of examples M1, M2, and M3. In each table, the first column indicates the instance reference. In the second column, the values |V|, |E|, |V|´ and |E|´ represent, respectively, the number of nodes and edges of the graphs G_1 and G_2 in each instance and the number of changes imposed on concepts and on their relationships. The third column indicates the average similarity percentage (from the ten executions) of the compared graphs and the execution time in seconds, obtained by the GCMGIP algorithm.

Instance	G_1 and G_2 vertex and edge sets sizes and number of changes				GCMGIP	
	|V|	|E|	|V|´	|E|´	(%)	Time(s)
1	14	14	4	9	89.78	0.06
2	17	18	9	14	76.17	0.08
3	15	16	5	14	90.51	0.09
4	27	32	24	28	68.36	0.24
5	10	10	7	7	80.97	0.05
6	30	41	23	39	64.36	0.12
7	28	35	18	22	74.18	0.20
8	14	15	12	13	70.77	0.08
9	12	14	10	14	79.12	0.05

Table 1: Experimental Results (group M1).

Instance	G_1 and G_2 vertex and edge sets sizes and number of changes				GCMGIP	
	|V|	|E|	|V|´	|E|´	(%)	Time(s)
1	14	14	0	0	100	0.06
2	17	18	0	0	91.76	0.09
3	15	16	0	0	100	0.08
4	27	32	0	0	100	0.17
5	10	10	0	0	100	0.05
6	30	41	0	0	100	0.22
7	28	35	0	0	100	0.17
8	14	15	0	0	100	0.06
9	12	14	0	0	100	0.05

Table 2: Experimental Results (group M2).

Instance	G_1 and G_2 vertex and edge sets sizes and number of changes				GCMGIP	
	|V|	|E|	|V|´	|E|´	(%)	Time(s)
1	14	14	4	9	89.78	0.05
2	17	18	9	14	82.66	0.08
3	15	16	5	14	92.51	0.08
4	27	32	24	28	68.36	0.20
5	10	10	7	7	80.97	0.05
6	30	41	23	39	64.36	0.15
7	28	35	18	22	74.17	0.20
8	14	15	12	13	70.77	0.06
9	12	14	10	14	79.12	0.06

Table 3: Experimental Results (group M3).

From the information in the tables, it can be observed that the GCMGIP algorithm succeed to identify, in average, 89.77% of similarities between the maps compared in a very short execution time for all instances. As the concepts and their relationships are unchanged in the M2 group, the GCMGIP presented its best performance in this case, succeeding to recognize completely all but one instances. Also, the algorithm identified with 100% of similarity, all instances of the M0 group, whose pair of maps are completely identical.

6 Conclusions and future work

In this work, concept maps are described as attributed graphs and its comparison was performed using graph matching, more specifically, graph isomorphism. For its solution, a heuristic algorithm was used to automatically compare the maps and compute their similarities. The experimental results obtained so far indicate that the use of automated techniques for the comparison of concept maps is suitable for several applications. For instance, it can provide an efficient way of monitoring and evaluation of procedures for learning as well as the classification of documents represented by concept maps.

This proposal is generic and can be applied to concept maps represented in any language. But, as it needs a words comparator, a preliminary instantiation of this proposal was implemented to compare concept maps described in the English language. The adaptation to any other language depends only on the replacement of the module for the comparison of words.

Future works will mainly consist of the validation and subsequent implementation of the described techniques in real situations of learning, applying them to concept maps, eventually of different sizes, constructed by Computer Science students. Furthermore, we intend to use concept mapping for summarizing discussions in thematic forums and also for representing and comparing ontological concepts.

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AN APPROACH TO COMPUTER-AIDED LEARNING ASSESSMENT

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Abstract. Advances in Computer Science have supported considerably better results in the development of educational environments. Such technologies are the foundation of tools and environments aimed at facilitating teaching, learning, and assessment. The goal of these initiatives is, ultimately, to favor learning and to respect students' idiosyncrasies, their unique ways of learning. In this paper we present an approach to computer-aided learning assessment: its supporting educational concept is *meaningful learning* and the computational tools used to implement it are *domain ontologies* and *genetic algorithms* (GAs); its main focus is *learning assessment* via *concept maps* (CMs). In the proposed approach, domain ontologies drawn by teachers for topics of disciplines are searched by a GA, which builds best-match populations of CMs semantically comparable to students' CMs. This way, we can assess individual learning, taking into account idiosyncratic forms of learning.

1 Introduction

In the area of school education, many researchers support the idea that the educational process can be greatly enhanced with the use of technologies resulting from advances in Computer Science (Jonassen, 1996). These technologies allow for the construction of computational environments that aim at facilitating teaching, learning, and sometimes learning assessment. With the dissemination of distance learning, however, learning assessment has become a constant concern. In large-scale virtual learning environments, teachers have to cope with the assessment of virtual groups of, for example, hundreds of students. Concerning the construction of educational environments, two fundamental problems arise: the choice of a learning theory to serve as the basis for the environment and, even more important, the identification of implementable aspects of this theory (Giraffa, 1999). In Educational Psychology, Cognitivism has played a major role in the last decades. It emphasizes the internal processes that lead to the construction of knowledge. Under Cognitivism, self-knowledge and awareness of idiosyncratic ways of learning are important issues, as people learn the same thing in different ways.

In the sixties, David Paul Ausubel, a cognitivist author, developed the *Assimilation Theory* (Ausubel, 1968; Ausubel, 2000). According to Ausubel, human beings learn meaningfully via acquisition and retention of concepts and propositions, which are stored in their cognitive structures in a particular, idiosyncratic way. This particular way of storing concepts and propositions is what forms the meanings human beings assign to experiences. A new meaningful learning process starts with the definition of an anchorage point in the cognitive structure, called *subsumer*, to which new concepts are connected. As a result, new learning essentially depends on the quantity and quality of the subsumers, as well as their stability and differentiability in the apprentice's cognitive structure (Ausubel, 1968). Applying adequate mental processes, called *progressive differentiation* and *integrative reconciliation*, human beings construct the knowledge stored in their cognitive structures. An immediate consequence of this theory are that humans can construct the same knowledge differently – using different subsumers, or different connections between new concepts and subsumers. Another consequence is that one of the major aspects of teaching is finding sufficiently mature subsumers able to serve as stable anchorage points to the new concepts.

Although apparently simple, Ausubel's ideas are not easily put into classroom practice without proper understanding of the processes through which people learn meaningfully, i.e., there is a fundamental necessity of learning the concepts of progressive differentiation and integrative reconciliation before applying them to usual school topics. Aware of this difficulty, Joseph D. Novak developed a pedagogical tool called *concept map* (CM) (Novak, 1998; Novak & Gowin, 1984). According to Novak, a CM represents part of a person's cognitive structure, revealing his or her particular understanding of a specific knowledge area. It contains concepts and propositions in graphical form, and it is constructed by the continued application of progressive differentiation and integrative reconciliation. This way, a sequence of CMs constructed by a person can illustrate the evolution of this person's understanding of the topic (Rocha & Favero, 2004). The step-by-step construction of a CM can also highlight personal preferences, as some people prefer to specialize new concepts from more general ones (in a top-down approach to learning), while others prefer to generalize new concepts from specialized instances (bottom-up approach).

Consequently, CMs are a viable, computable, and theoretically-sound solution to the problem of expressing and assessing students' learning. They can be used, among many other things, as alternatives to usual essays, decreasing the amount of work demanded from the teacher during assessment. Nevertheless, the assessment of hundreds of CMs is still a considerable source of effort. Educational environments based on CMs focus on automating parts of this process.

In this article, we present an approach to computer-aided learning assessment via Concept Maps. It is based on Artificial Intelligence techniques (Rocha, Costa Jr., & Favero, 2004), such as ontologies and genetic algorithms. This approach was developed to facilitate the construction of CM-based environments aimed at teaching, learning and, most of all, assessment. It is an alternative to mere CM comparisons, which hinder personal ways of constructing knowledge. Some environments, based on CMs and aimed at assessment, have already been described in the literature (e.g. Araújo, Menezes, & Cury, 2003; Cabral & Giraffa, 2002). The general tendency of these environments is to compare the CM developed by student to a reference CM constructed by the teacher or by a specialist. This approach forces the comparison between potentially different – and potentially correct – understandings of the same reality. The result of this comparison can be used to assign a degree to a student, but it can hardly be considered learning assessment, from a cognitivist perspective.

As an alternative approach, we propose the use of two complementary Artificial Intelligence techniques: (i) domain ontologies, which serve as repositories of knowledge related to concepts of a topic of a discipline; (ii) a genetic algorithm (GA) capable of emulating the cognitive processes described in the Assimilation Theory, and capable of generating various CMs based on the domain ontologies, with the help of an inference engine. We suggest that domain ontologies, which concentrate the knowledge of an area or topic, be explicitly built by teachers or automatically extracted from a set of previously validated CMs. Furthermore, students are expected to express their conceptual learning, mapping the concepts used in the ontology. In order to do this, students can use a CM editor, for example. Eventually, students submit their CMs for automatic assessment. Detailed explanations on the roles of teachers and students in the approach, as well as how assessment is accomplished in an idiosyncratically, cognitivist-aware manner, are provided in the next sections of this article.

This article encompasses seven sections. Section 2 details the relationship between Ausubel's Assimilation Theory and Novak's Concept Maps. Section 3 describes the proposed approach from the teachers' perspective. Section 4 describes the role of the students in the approach (working individually or cooperatively). Section 5 describes the steps necessary to accomplish assessment: the generation, by the GA, of populations of CMs comparable to the student's CM, and the results generated by an assessor component. Finally, Section 6 describes an educational environment developed according to the approach proposed in this article (called CMTool) and lists future research. Section 7 presents our final considerations.

2 The Assimilation Theory and Concept Maps

The Assimilation Theory (Ausubel, 1968; Ausubel, 2000) was developed by David Paul Ausubel in the 1960s and explains learning as the immersion of new concepts in the individual's cognitive structure – a mental structure in which knowledge organization and integration are processed. The main concept of this theory is meaningful learning: a process in which new information is linked to some specific relevant aspect of the individual's cognitive structure (subsumer). A CM about meaningful learning can be seen in Figure 1. Other basic principles described in the Assimilation Theory are progressive differentiation (in which learners increase the degree of elaboration of a concept as they increase their knowledge about it) and integrative reconciliation (when the learner identifies dimensions of relationships between components not previously connected), which are cognitive processes that explain the subsumption of new concepts in the cognitive structure. Integrative reconciliation can be of two distinct types: superordinate or combinatorial (Rocha, Costa Jr. & Favero, 2007).

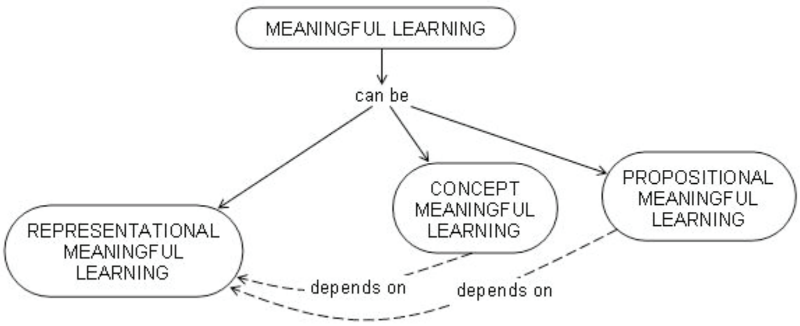

Figure 1. Concept map about meaningful learning (adapted from (Rocha, 2007)).

The systematic use of progressive differentiation, superordinate or combinatorial integrative reconciliation, during CM construction, can shed light on individual learning preferences. Some students prefer a top-down approach to learning, favoring progressive differentiations when constructing their CMs, while others tend to favor a bottom-up approach, making extensive use of integrative reconciliations. Awareness of personal learning styles allows for individualization of teaching (from the teacher's perspective) and more efficient learning, via self-knowledge (from the student's perspective).

CMs are semi-formal knowledge representation tools that use natural language to represent concepts and propositions. As such, they profit from the ease of creation and use: CMs have been used to teach a variety of different disciplines, to many different ages and teaching levels, including kindergarten (Mancinelli et al., 2004; Afamasaga-Fuata'I, 2004). They have also been used as a tool to organize and present information, for course or curriculum development, for navigation support, and for learning assessment. Nevertheless, this ease of use causes an undesirable side effect: ambiguity, which makes it difficult to assess the knowledge expressed in CMs (Costa Jr., Rocha, & Favero, 2004). Much has been done, however, in the field of CM disambiguation (Cañas et al., 2008).

As mentioned in the previous section, the assessment accomplished through mere comparison of a student's CM and a reference CM is not in accordance with cognitivist principles, as it forces students to construct their knowledge in a way that mimics the knowledge constructed by the teacher or expert who built the reference CM. This approach does not address the fact that humans construct knowledge in a number of different ways. An alternative is to compare students' CMs to populations of CMs generated by a mechanism responsible for building correct CMs based on an ontology.

Our approach recommends the use of ontologies to generate search spaces of possible correct CMs. These search spaces are then searched by a genetic algorithm (GA), responsible for finding the *best-match CMs*, i. e., the CMs in the search space that can be compared to the student's CM. Assessment is accomplished by analyzing the semantic difference between the student's CM and the CMs found by the GA. This is a general approach to learning assessment capable of coping with situations not addressed by the simple comparison of the student's CM to a reference CM. For example, a student who claims that "plants have leaves" will be assessed similarly to another who states that "leaves are part of plants" (Synonymy). Another student who states that "plants generate oxygen" will be assessed correctly, even if the ontology contains only the propositions "leaves generate oxygen" and "plants have leaves" (Inference).

3 Ontology Creation

The approach proposed in this paper recommends that domain ontologies, which concentrate the knowledge of an area or topic, be either explicitly built by teachers or automatically extracted from a set of previously validated CMs. Ontology mining has been a proficuous field in Knoweledge Engineering in the last few years (Cheng et al., 2004). If automatic ontology consolidation is not provided, educational environments compliant with this approach should allow for the explicit creation of ontologies by teachers. In accordance with cognitivist principles, the role of teachers in the approach proposed in this article is to help students in their journey towards the construction of their own knowledge. Later on, teachers are expected to assess students' learnings, respecting idiosyncrasies. To help teachers, the approach recommends the use of a user-friendly tool to create domain ontologies related to the topics of their disciplines. The goal of this step is to allow for the creation of a repository of knowledge related to the topic being taught, in order to liberate teachers from the work overload deriving from the analysis of a multitude of CMs.

In the approach, domain ontologies are used to create common vocabularies for the different topics of a discipline. They are also used to create classification and semantic relationship rules between these concepts, so as to make it possible to infer new knowledge from the knowledge expressed in the ontology and, as a consequence, help in students' automatic learning assessment. In order to infer new knowledge from ontologies, environments developed according to the approach must make use of an inference engine, capable of making inferences from axioms described in the ontology. Figure 2 illustrates the graphical representation of a domain ontology about data communication. It was created in an ontology editor (On_Tool), which is part of CMTool (Rocha & Favero, 2004), an environment developed according to the approach described in this article.

On the right side of Figure 2, it is possible to see the taxonomy of linking phrases prescribed by the approach. It contains the possible semantic dimensions of relationships between concepts, and the linking phrases that instantiate these dimensions. For example, the semantic dimension *process* can be instantiated by the linking phrases *is used by* or *is supported by.*

When teachers build the ontologies, they are not required to inform linking phrases, but only the semantic dimensions of relationships between concepts. This is one of the major differences between CM construction and ontology construction. However, in some cases, teachers can limit the linking phrases that can be used in the construction of propositions, in order to improve the accuracy of the CMs generated by the genetic algorithm. As detailed in Section 5, if a student's CM contains the propositions (i) <DIRECT COMMUNICATION has MANY PHYSICAL CONNECTIONS>, (ii) <DIRECT COMMUNICATION is characterized by MANY PHYSICAL CONNECTIONS>, or (iii) <DIRECT COMMUNICATION is not CHEAP>, all of them will be considered valid by the assessment mechanism, because propositions (i) and (ii) denote explicit knowledge (the *characterization* dimension can be validly instantiated by <is characterized by> and <has>), and proposition (iii) denotes knowledge validly inferred from the ontology.

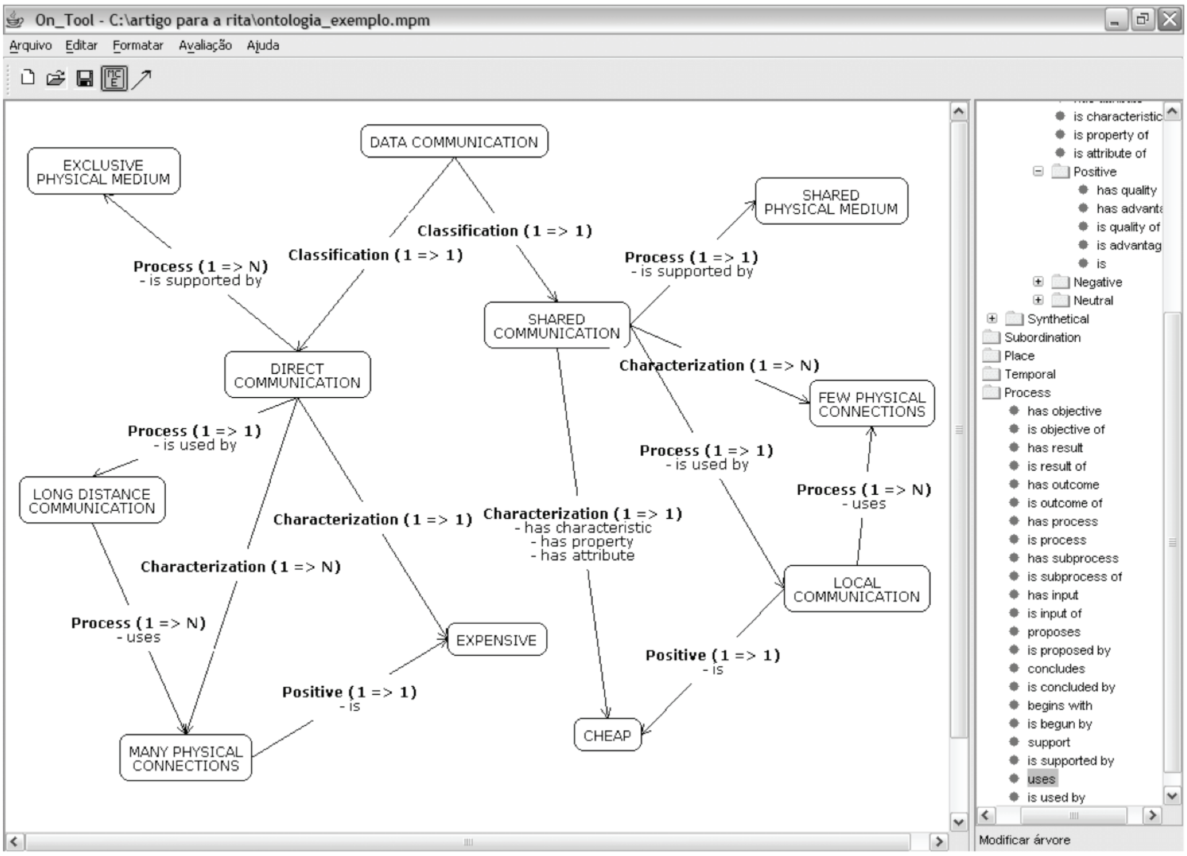

Figure 2. An ontology about data communication constructed in On_Tool.

If students construct propositions that cannot be validated by the assessment mechanisms based on the ontology, it is desirable that teachers be notified by the environment, as this event can denote the occurrence of valid propositions not expressed in – and not inferable from – the ontology. Consequently, teachers can begin a negotiation process with students, in order to reach an agreement about the validity of the suggested proposition. If the validity is confirmed, the environment should insert the proposition in the ontology, with the teachers' acknowledgement.

4 Concept Mapping

In accordance with the cognitivist view of meaningful learning, students are supposed to construct their knowledge by establishing semantic connections between the concepts related to the study of a specific topic of a discipline (described in the domain ontology built by the teacher). They are expected to construct their concept maps by the continued application of progressive differentiation and integrative reconciliation. The knowledge represented in the CMs can then be submitted for learning assessment.

In order to help students, environments compliant with the approach should provide a CM editor for student construction of concept maps. The CMs should use the concepts of an ontology stored in the environment. After construction, they should be submitted for assessment. Figure 3 presents a CM built from the concepts of the ontology illustrated in Figure 2. This CM represents a student's understanding of the topic, and can be submitted to the learning assessment mechanism prescribed by the approach.

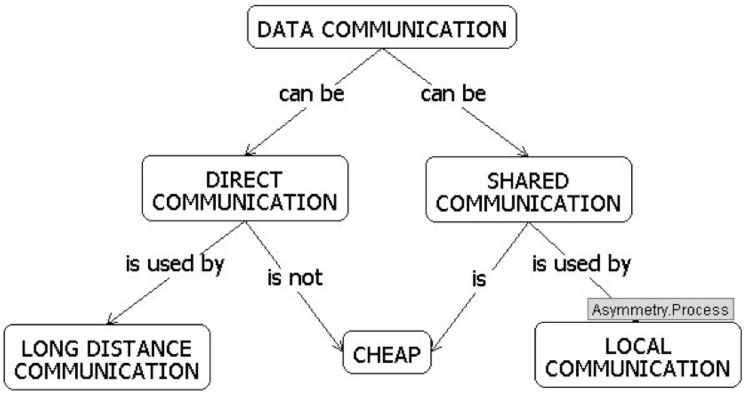

Figure 3. A concept map about Data Communication.

When a CM is being built, environments should help students during the choice of linking phrases, because this is the moment in which mappers explicitly define meanings. This can be done by showing pre-categorized semantic dimensions – and their respective linking phrases – to students. When a student decides to connect two concepts, he/she must be aware of the semantic dimension under which these concepts will be connected. This step is crucial, because it is the input for other definitions, like the choice of the most inclusive concept in a proposition, i.e., the concept that will be the subject of the assertion corresponding to the proposition in the CM.

In Figure 3, the student chose to connect the concepts SHARED COMMUNICATION and LOCAL COMMUNICATION with the *process* dimension, and the linking phrase that instantiated this dimension was <is used by>. Under these circumstances, the most inclusive concept is SHARED COMMUNICATION. The student could have chosen another semantic dimension for the relationship between these two concepts as, for example, the *classification* dimension. With this choice, the student would be able to construct the proposition <SHARED COMMUNICATION can be LOCAL COMMUNICATION>. However, this proposition is expected to be considered inaccurate by the assessment mechanism, because it is not supported by the underlying ontology. Figure 3 shows the complete taxonomy dimension of the linking phrase chosen by the student. This dimension should be stored internally, and the final CM should present only the linking phrases, for readability purposes.

Variations of the steps described in this section can be used during the learning process. Among other possibilities, it is possible to use interdisciplinary ontologies, contextualize and assess CMs under more than one ontology, or assess CMs produced collaboratively by a group of students, as a result of meaning negotiation among them.

5 Assessment

In this section, we present an example that shows the functioning of the GA. For this learning task, the teacher constructed the ontology illustrated in Figure 2. Internally, the ontology should be stored as axioms, in order to allow for inferences (and further exploration of the search space by the GA).

Based on the axioms, the GA can generate propositions (using concepts from the ontology and linking phrases from the taxonomy) and ask the ontology if they are valid. Valid propositions should be stored for posterior creation of individuals (CMs) in the populations generated by the GA. These individuals have to be evaluated, and a fitness value must be assigned to each one, based on its semantic defference from the student's CM (the GA privileges CMs that use the same concepts and phrases found in the student's CM). The final objective is to find a set of *best-match CMs*: those that are similar to the student's CM and valid according to the ontology. For more information on GAs, please refer to (Goldberg, 1989), and for a detailed description of the inner workings of the GA defined by the approach, refer to (Rocha, Vieira, Costa Jr., & Favero, 2004).

The first step taken by the GA, after a CM submission for assessment, is to generate several propositions (sets of two concepts connected by a linking phrase). Each proposition has to be evaluated by an inference engine, based on the ontology. Invalid propositions should be discarded. Valid propositions should be kept for creating populations of CMs. CMs are, thus, formed by grouping propositions in a number equal to the propositions present in the CM submitted for assessment.

Individuals in the population (CMs created in the previous step) have to be evaluated according to a fitness function that measures their semantic difference to the student's map (maps similar to the student's are scored highly). Afterwards, the GA selects the best individuals to be the parents of the next population. The next generation is created with the propositions (genes) of the parents. The best individuals of the previous generation are kept in the current generation. Additionally, as in nature, mutation should be allowed with a certain probability. When a mutation occurs, the GA should use a new proposition (formed from the ontology and from the taxonomy, and considered valid by the inference engine). Mutations are an important part of GAs, as they allow for further exploration of the search space, and inhibit premature convergence. This process should be repeated until a best-match CM is found. The best-match CM is then presented to the student as an alternative to the initial CM. The GA ensures this map is similar to the student's, so that it is simple for the student to analyze possible misconceptions in the original CM submitted for assessment.

Table 1 presents excerpts of a CM assessment. The results are organized in four parts. Part (a) reports if the concepts used in the CM submitted for assessment are related to the learning task underway, and if the learner's propositions are valid in the context under analysis. In order to do this, relationship dimensions should be validated. Part (b) presents the semantic comparison of the assessed CM to the best-match CMs generated by the GA. The objective is to present to the learner valid forms of mapping the knowledge represented in the ontology of the learning task underway. The semantic distance between the assessed CM and each one of the best-match CMs should be calculated. If any of the calculated values is different from zero, detailed information containing the possible alternatives to the identified misconception should be presented to the learner. Part (c) details the actions taken by the GA to construct the best-match CMs presented in part (b). The objective is to show to learners how to construct forms of knowledge representation alternative to their own (presented in part (a)). Finally, part (d) presents the list of concepts that, although present in the domain ontology, were not mapped by the learner. The list may indicate the need for reinforcement of specific topics of the discipline.

Assessment Results
a) Hierarchical Structure and Learning Types 1. Assessed CM:{<DT COMM,can be,DR COMM>,<SH COMM,has type,DT COMM>} 1.1. Concepts: { DT COMM, DR COMM, SH COMM} 1.2. Propositions: p1=< DT COMM, can be, DR COMM >, p2=<SH COMM, has type, DT COMM > 1.3. Valid Hierarchies: {<DT COMM,Asymmetric.Definition.Synthetical.Classification,DR COMM >} 1.4. Invalid Hierarchies: {<SH COMM,Asymmetric.Definition.Synthetical.Classification,DT COMM >} 1.5. Valid Propositions: p1=<DT COMM,can be,DR COMM> 1.6. Invalid Propositions: p2=<SH COMM,has type,DT COMM> ...
b) Semantic Analysis 1. Best-Match CMs Generated by the GA: CM1={<DT COMM,can be,DR COMM>,<DT COMM,has type,SH COMM>} 1.1. Concepts: CM1 Ì { DT COMM, DR COMM, SH COMM} 1.2. Propositions: CM1 Ì {p1=<DT COMM,can be,DR COMM>, p2=<DT COMM, has type, SH COMM>} ...
c) Actions for the Reconstruction of the Best-Match CMs CM1: Create propositions p1, p2 Combine propositions p1, p2 (differentiate <DT COMM> progressively) ...
d) Ontology Concepts Absent in Assessed CM: {EXCLUSIVE PHYSICAL MEDIUM, LONG DISTANCE COMMUNICATION, MANY PHYSICAL CONNECTIONS, EXPENSIVE, CHEAP, SHARED PHYSICAL MEDIUM, FEW PHYSICAL CONNECTIONS, LOCAL COMMUNICATION}

Table 1: Excerpts of a CM assessment

6 CMTool and Additional Research

CMTool (Rocha, 2007; Rocha & Favero, 2004) is an environment compliant with the approach presented in this article. It was developed to validate the approach and its implementability. Its block diagram is illustrated in Figure 4. It encompasses seven modules: the administrator, a CM editor, an ontology editor, the assessor, a genetic algorithm, an inference engine, and a repository.

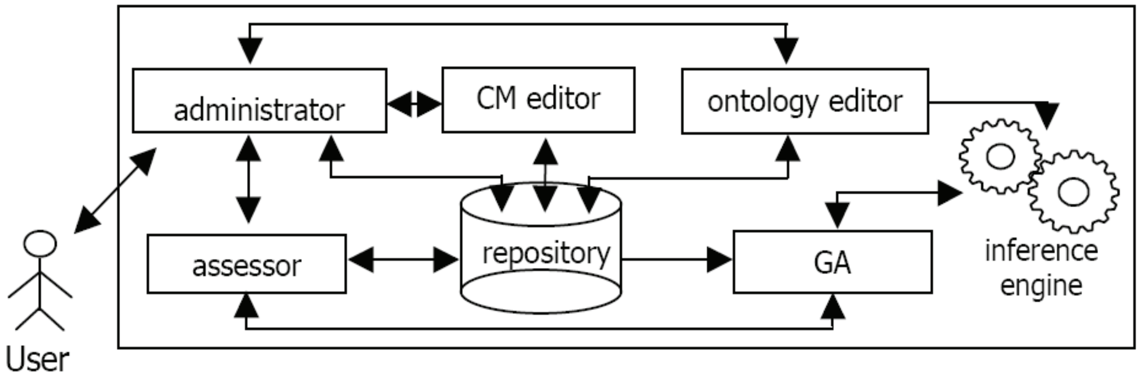

Figure 4. Architecture of the CMTool environment.

The administrator is responsible for controlling environment access. The CM editor implements a visual language for constructing CMs in compliance with the principles of the Assimilation Theory. The ontology editor, called On_Tool, is used to help to construct domain ontologies that correspond to learning tasks. The GA, based on the domain ontology for the task underway, generates populations of CMs, which are used in learning assessment. The inference engine helps the GA in the construction of CMs by analyzing the validity of propositions not explicitly expressed in the ontology. The assessor uses the results generated the GA to produce a complete assessment of the learning of a student. The repository contains a taxonomy of linking phrases, user information, instances of search spaces generated the GA, domain ontologies, and users' CMs. In experiments conducted at the Federal University of Pará (UFPA), in Brazil, with Computer Science students, CMTool has been successful in assessing students' personal understandings of specific topics, according to cognitivist principles. Rocha (2007) details results of these experiments.

Additional research can focus on automatic generation of axioms for non-trivial types of conceptual relationships. The taxonomy of linking phrases contains many semantic dimensions in which concepts can be related (e.g. place, process, temporal), some of which are easily axiomatized. A future development, thus, is to study the axiomatization of these dimensions, in order to improve the inference mechanism and, as a result, increase accuracy in searches.

7 Final Considerations

In this article we presented an approach to learning assessment via concept maps. This approach makes extensive use of Artificial Intelligence techniques (such as ontologies and GAs), in order to make it possible to comply with cognitivist principles. Concerning learning assessment via CMs, we found out that the dominant idea is to compare students' CMs with a reference CM. This approach is not efficient, as it does not take into account idiosyncratic forms of knowledge construction. As an alternative, our approach uses a GA capable of generating families of CMs based on ontologies inserted by teachers.

It could be argued that our approach works only with very specific ontologies. In fact, the contrary is true. The GA is based on mathematical axioms, which can be applied to any ontology built in the framework of the Assimilation Theory. Ontologies generated are stored as axioms. This facilitates the sharing and exchange of knowledge represented in the ontologies, and also makes it possible to translate them to other representation languages, like the ones used in Semantic Web implementations.

We emphasize that the approach described herein has already been implemented in an environment (CMTool), which was successful in assessing students' CMs. We understand this research is a positive step in the automation of cognitivist practices. We are aware that enhancements can be made and our next goal is to further develop the approach.

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APPLYING NOVAK'S NEW MODEL OF EDUCATION TO FACILITATE ORGANIZATIONAL EFFECTIVENESS, PROFESSIONAL DEVELOPMENT AND CAPACITY-BUILDING FOR THE NEW TEACHER ALLIANCE

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Abstract. Managing a multi-stakeholder, complex statewide teacher improvement project presents many challenges. Fostering effectiveness and sharing lessons learned among the partners and stakeholders is essential. Concept maps and Novak's New Model of Education (2004) are being used to facilitate organizational effectiveness, professional development, and capacity building for The New Teacher Alliance (NTA). NTA is a partnership of seven (7) school districts and two (2) educational service districts (ESD) in Washington State. Its mission is to implement model induction programs for novice teachers. NTA focuses on building district capacity to retain new teachers for the crucial first five years of teaching. Its work is guided by five standards of effective induction and conceptually associated elements. Using CmapTools, a "skeleton expert" concept map was created from these five standards and associated elements (sub-concepts). NTA partners are enhancing and extending this "skeleton expert" concept map by contributing work products, and by further differentiating and integrating the conceptual elements. Work products are accessible to participating partners via the Cmap. A web-version was launched in June 2008 to share the NTA knowledge model and partner's work products with other educators in Washington State, the United States, and globally. This paper presents progress and results-to-date.

1 Novak's New Model of Education

Drawing on over thirty years of research and successful results using concept mapping to foster meaningful learning for students and teachers, Novak and Cañas (2004) presented a new model for education based on the use of "skeleton expert" concept maps created with CmapTools. Rooted in Ausubel's (1963) theory of meaningful learning, Novak's New Model calls for students to extend the "skeleton expert" concept maps by further differentiating the concepts, by increasing the integration through new cross-links that clarify conceptual inter-linkages, and by adding knowledge resources to the Cmaps.

The target application of Novak's New Model is the improvement of meaningful student learning and achievement in science and math. Novak and Canas (2004) call for more research on how to devise 'skeleton expert' concept maps and how to employ them in teaching and learning.

One innovative application of "skeleton expert" concept maps is as facilitative tools to increase the effectiveness of work in an organization. Peter Drucker (2001), who coined the term "knowledge worker," argued that the job of a knowledge worker is to be effective. He defined effectiveness as "contribution to the performance of the organization-as-a-whole," and held that increasing his or her effectiveness may be the only way to significantly raise the level of the knowledge worker's performance and achievement.

A "skeleton expert" concept map of an organization's goals and objectives provides a context for meaning-making that helps members of the organization understand how their work contributes to the organization's goals, i.e., it provides a context for understanding what is required in order for contributions to be effective.

2 Application of Novak's New Model of Education to Improve Organizational Effectiveness, Professional Development and Capacity-building

The New Teacher Alliance (NTA) is an initiative of the Center for Strengthening the Teaching Profession (CSTP). CSTP is an independent, nonprofit organization that fosters student achievement by improving the quality of teaching in Washington State. NTA is a partnership of seven (7) school districts and two (2) educational service districts (ESD). Its mission is to provide leadership and support to help school districts implement model teacher induction programs for novice teachers. NTA focuses on building district capacity to retain new teachers for the crucial first five years of teaching by focusing district effort on five standards of effective induction – hiring, orientation, mentoring, professional development and assessment for learning.

In a multi-stakeholder initiative such as the New Teacher Alliance, the "organization-as-a-whole" is distributed and consists of all the partner teams, as well as the CSTP staff responsible for project leadership and management. The geographic distance among partners and relatively infrequent meetings make it challenging to keep the "organization-as-a-whole" and its objectives center-front. These factors also make it challenging for CSTP staff to be able to accurately assess how the capacity of the organization-as-a-whole is developing, and to identify current capacity gaps in a just-in-time manner. Jeanne Harmon, Executive Director of the Center for Strengthening the Teacher Profession (CSTP) put it this way: "Managing a multi-faceted, complex statewide project such as [the New Teacher Alliance] is a huge challenge, and sharing lessons learned amongst the many partners is absolutely critical to our success."

To address this challenge, CSTP contracted with Sound Knowledge Strategies, LLC to create a Cmap- "Successful Teacher Induction in Washington State: Standards for Beginning Teacher Induction" (Figure 1). The Standards and Elements represented in the Cmap were drawn from a document, "Effective Support for New Teachers in Washington State: Standards for Beginning Teacher Induction." The standards were identified by a group of master teachers, district administrators, mentors, and were reviewed by experts in the field. The concept map of the Standards and Elements, therefore, qualifies as a "skeleton expert" concept map.

The Cmap facilitates sense-making, alignment of partners' work with project goals, and enables partners' work and insights to be shared within NTA, as well as with the wider education community interested in teacher induction. NTA is applying Novak's New Model of Education not only to foster meaningful learning for individuals, but also to provide a knowledge-based, sense-making infrastructure for a distributed organization. The "skeleton expert" concept map serves as a knowledge-building infrastructure as well as a cognitive scaffold.

Reporting on the contribution the concept map makes, Mindy Meyer, NTA Project Director, notes: "The concept map gives a visual representation of our standards that helps many of our team members see the work from a holistic viewpoint and allows them to make connections between the standards and elements and their impact on each other."

3 Procedures and Results-to-Date

The initial step was to translate the text version of the standards and elements in "Effective Support for New Teachers in Washington State: Standards for Beginning Teacher Induction" into a Cmap – Figure 1.

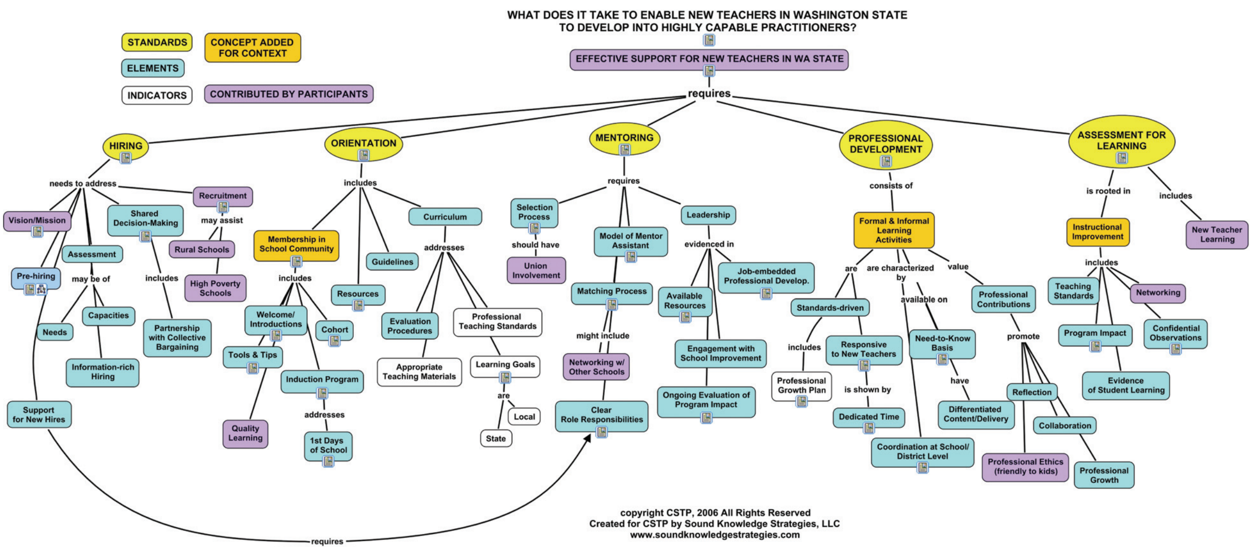

Figure 1. Standards and Elements for Effective Support for New Teachers in Washington State – November, 2006 version

The concept map was used by twenty (20) team members including, mentors and administrators, in the New Teacher Alliance during a professional development workshop in November, 2006. Participants used the concept map as a way: 1) to see the whole conceptual landscape for successful teacher induction, 2) to identify the standards and elements their own work-to-date addressed, 3) to locate the standards and elements that represented areas of collective strength, 4) to identify those where no work had yet been done (gap analysis), and 5) to add their own contributions to further differentiate and integrate the concepts in the Cmap.

For example, participants identified a cross-link between two non-adjacent elements: "Support for New Hires" and "Clear Role Responsibilities" – see Fig. 1 above. They also identified the concepts that would be components of a concept map for the "Prehiring" element. The new sub-concept map was attached to the "Prehiring" concept node (Figure 2).

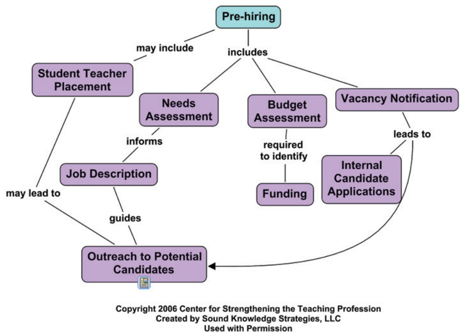

Figure 2. "Skeleton Expert" Map "Prehiring" Element as "Fleshed-out' by NTA Partners

Working in pairs, or teams of three, participants wrote a phrase to describe each of their work products on a separate Post-It note and attached the notes to the appropriate concept nodes on a 14"x17" hard copy printout of the concept map. During this work, reflective discussions took place about which elements the work supported. Each team's annotated concept map made areas of current capacity, as well as gaps, visible.

Throughout the workshop, a large (3' x 4') vinyl copy of the concept map was displayed on an easel in the front of the room. After the work in teams, a representative of each team was invited to bring the Post-It notes describing their team's work and to place them on the large concept map. The collective contributions gave a snapshot of NTA's current organizational capacity. It was immediately clear that most work had been focused on Hiring, Orientation, and Mentoring and, that less had been done for elements of the Standards for Professional Development and Assessment of Learning.

Generally, participants were enthusiastic about CmapTools and their use of the concept map to support sense making and effectiveness. The following comments were among those listed in response to the evaluation question: "What was the most useful part of the workshop?"

- "Placing activities on the concept map."
- "Versatility of the tool."
- "Developing a map from class input."
- "The ability to collect the broad picture with details that can clarify issues."
- "Collaboration with table group and hands-on exposure to the technique of concept mapping."
- "Understanding the concept map and working with it."

A few participants, however, reported finding the concept map confusing and indicated that more information on the link between the concept map and the standards would have been helpful. In response to the evaluation question: "What will you do differently as a result of this workshop?" one participant responded: "Think more clearly about the wide range of initiatives implied by the standards."

At the end of the workshop, Bowen provided a demonstration of how to upload digital documents to the concept map. It took about two months to get CSTP's Cmap server launched and to work out the details of getting the documents to the technical support person in charge of uploading them for each team. To date, fifty-eight (58) documents have been contributed. They include a wide-range of practical support tools such as:

- 5-Day New Teacher Orientation
- Mentor Interview Questions
- Goals and Roles of Mentoring Program
- Classroom Management 1-5
- Professional Development Plan
- Practice to Action
- Equity Handbook
- "So You Want to Teach?"

- New Teacher Support Survey.

During the 2006-2007 school year, Bowen worked with Meyer to define format guidelines for the documents that NTA partners are sharing. Initially, several MS Publisher documents were attached but these could not be opened. This led to MS Word, MS Excel, PDF, and jpeg being the standard allowable formats. NTA participants send their Publisher files to the NTA project assistant who uses a software program designed for that purpose to translate them into PDF files. Bowen also developed a five-item assessment rubric and used it to assess each of the documents contributed by the partners. The five rubric items are:

- Alignment (Content of document aligns with Standard and Element to which it's contributed.)
- Effectiveness/Impact (Does the document convey systemic impact on the whole school district.)
- Meaningful learning (Document provides evidence that team has incorporated new information to improve existing knowledge and practice related to this Element.)
- Self-assessment/Reflective practice
- Professional contribution (Does the work product advance the knowledge and practice of NTA?)
- Continuous improvement

NTA partners are using the rubric as a self-assessment tool to guide the revision and upgrading of their work products, which will be shared via the web-version of the concept map that was launched in June.

In March, 2008, Meyer met with seven NTA participants to review and extend the concept map. Participants added nine (9) new concepts, "fleshed-out" four (4) elements from the initial "skeleton expert' concept map - including "Formal and Informal Learning Activities and Resources" (Figure 3), and added five (5) new cross-links - indicated in purple in Figure 4. They also suggested creating a cover sheet that would include information about each document's context, purpose, goals, reflection, and contact person so that interested parties can have a clearer sense of each document and why it was created.

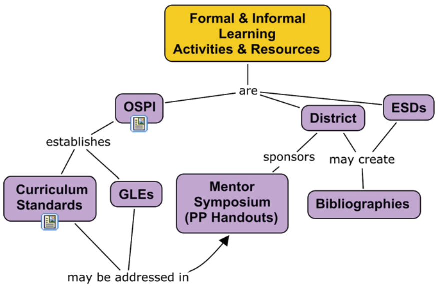

Figure 3. Concept –"Formal & Informal Learning Activities & Resources" "fleshed-out" by NTA Partners

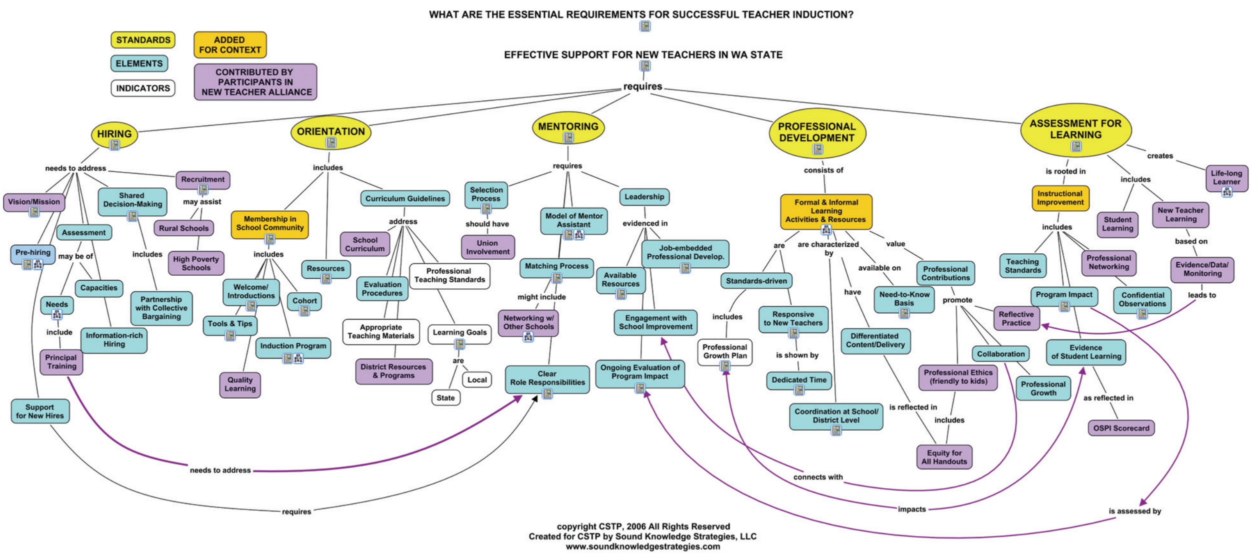

Figure 4. Standards and Elements for Effective Support for New Teachers in Washington State – with March, 2008 NTA partner additions

The web page version of the concept map re-titled as "New Teacher Induction Standards is accessible from the NTA homepage: http://www.cstp-wa.org/Navigational/New_Teacher_Project/New_Teacher_Alliance.htm on the Center for Strengthening the Teaching Profession's website. The web-based Cmap is a resource for K-12 administrators and leaders in Washington State and beyond who seek to create, high-quality, high-impact teacher induction initiatives.

The resources are available for re-use by educators via a Creative Commons License. The "Attribution, Non-Commercial, Share-Alike" License allows derivative works and modifications to be made provided they are not used for commercial purposes and are shared under the same Creative Commons License as the original work. The presence of the Cmap and its knowledge resources in the dynamic global Creative Commons enhances the potential for its widespread impact.

NTA Participants will continue to add documents and knowledge resources during the remaining eighteen months of the project. It is anticipated that this will result in the development of the first comprehensive knowledge model to addressing the induction of new teachers.

4 Other Uses of "Skeleton Expert" Concept Map

Project Director, Mindy Meyer uses the Cmap to assess individual team capacity and the collective capacity of the project-as-a-whole. It provides a way to "take the pulse" of areas where partners are excelling and where they may need assistance. Meyer reports that the concept map "allows districts to see the standards in a visual way that shows the interconnectedness of the work. It also creates an opportunity for the alliance partners to build from each other's work."

There is a link to a jpeg image of the concept map on the New Teacher Alliance website and a segment of the concept map has been included in "New Teacher Alliance: Improving Teacher Induction in Washington State," which is available on the NTA website.

5 Summary

The application of Novak's New Model of Education to support organizational effectiveness, professional development and capacity building by the New Teacher Alliance is generating positive results. Partners are actively "fleshing out" the "skeleton expert" concept map of "New Teacher Induction Standards" by contributing their work products, by adding new elements, by further differentiating existing elements, and by strengthening conceptual integration by identifying new cross-links. They are taking leadership in suggesting ways to upgrade and improve the quality of the work products they contribute.

The impact of their work will reach beyond the seven (7) districts and two (2) education service districts (ESDs) when the webpage version of the Cmap is made public in May, 2008. The authors believe that when the map is publicly launched and its use by others becomes visible, that an enhanced sense of professional leadership and effectiveness for the educators participating in NTA is a possible result. It may be useful to design a way to assess or measure this impact.

6 Acknowledgements

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Tallinn, Estonia & Helsinki, Finland 2008

ASSOCIATING DOCUMENTS TO CONCEPT MAPS IN CONTEXT

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Abstract. To be useful, automatic document classification systems must accurately place documents in categories that are meaningful to users. Because concept mapping externalizes humans' conceptualizations of a domain, concept maps provide meaningful categories for organizing documents. Since electronic concept-mapping tools provide mechanisms for using concept maps for effective document access, using concept maps as means to classify documents provides at the same time a browsing system to access the classified documents. To enable automatically associating documents with the relevant concept maps, this paper presents a new top-down/bottom-up approach to classifying documents in the context of topically relevant concept maps. Using the target concept maps as context for extracting concepts from text, this approach generates concept-map-based indexing structures from documents and then indexes them under the concept map most compatible with the document. An experimental evaluation shows marked improvements in performance compared both to a previous bottom-up approach to this classification task and to a second baseline method using unstructured keyword-based indices.

1 Introduction

Automatic document classification is as a powerful tool to help people select and understand relevant documents, by placing documents in the context of topically related information. Electronic concept mapping tools such as the CmapTools suite (Cañas *et al*. 2004), provide an easy-to-use method for humans to generate rich structured descriptions of their conceptualizations –which can in turn be viewed as descriptions of topics of interest– and are widely used for browsing and sharing knowledge. Consequently, the development of tools to automatically associate documents with relevant concept maps would be useful both for helping people to find documents related to a topic of interest as they browse concept maps, and for helping people to understand documents, by suggesting relevant concept maps to provide additional information as they read documents.

In previous work (Valerio, Leake, & Cañas, 2007), we presented initial steps on a method for document classification in which documents are associated with concept maps, based on comparing the target concept maps to a set of concept map fragments generated automatically from the document, and presented an evaluation demonstrating the promise of that approach. The fragmentary concept maps were generated entirely bottom-up from the text in documents, without considering the set of target concept maps. This paper explores a new top-down/bottom-up approach, which exploits the context of a set of target concept maps to bias assignment of labels for concepts, in an algorithm for extracting concepts from documents. Instead of building a single representation for each document, the approach builds a family of representations; each one optimized for the context of a different target concept map, and then classifies the document by the concept map that generates the best-customized fit. We hypothesize that by using top-down guidance from each map when each index is generated, the resulting sets of concepts map will more closely resemble the concept maps defining the categories, and that this will increase classification accuracy.

The paper begins by describing concept maps and the use of electronic concept maps as a medium for knowledge construction and sharing. It then surveys some related work on associating documents to concept maps, frames our specific problem, and presents our algorithm. Finally it presents an evaluation comparing the new algorithm to the previous algorithm for generating concept-map-based indices, and to an additional baseline using only unstructured keyword-based indices, with encouraging results.

2 Concept map Knowledge Models as a Rich Context for Documents

Concept maps express concepts and relationships in a two-dimensional network, where nodes correspond to concepts and links correspond to concept relationships. Concept mapping was developed in the context of education (Novak & Gowin 1984), but more recently, it has been recognized as a useful tool for knowledge construction and sharing by domain experts. In contrast to formal network knowledge representation models, such as semantic networks, conceptual graphs, and text graphs, concept maps are described in informal terms; they use natural language for concept and link labels, and the concept-link-concept triples form simple natural language propositions.

The CmapTools concept mapping software (Cañas *et al*. 2004) from the Institute for Human and Machine Cognition (IHMC) provides a means for generation and sharing of electronic concept maps, and permits the construction of concept-map-based knowledge models which are collections of topically related linked concept maps with attached resources such as documents or images (e.g., Briggs *et al*. 2004). Figure 1 shows a concept map and a linked document resource as displayed by CmapTools. The rich knowledge provided by the concept map and associated resources is a useful context for human document understanding, if documents can be associated with the proper concept maps. The CmapTools system provides methods for annotating concept maps with documents by hand. However, for document sets that are too large to process by hand, or for automatically monitoring a document stream to suggest documents relevant to topics of interest (already captured in a concept map), it is desirable to develop automatic classification methods.

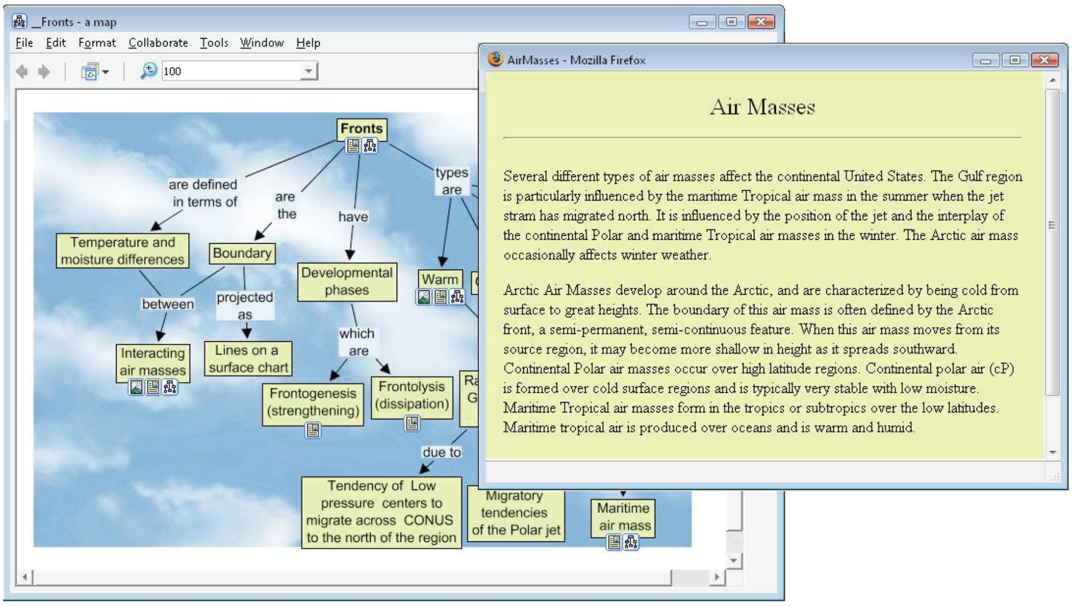

Figure 1. Example of a concept map and an attached document resource as displayed by CmapTools, from the STORM-LK knowledge model (Hoffman *et al*. 2001) .

An automated procedure to extract information from documents to produce concept-map-based indices must be able to recognize meaningful phrases for concepts and links in input documents in natural language. However, because concept maps are an informal representation, generating a "human-like" concept map, for use as a categorization index to compare to human maps, does not require complete analysis of the meaning of the documents. This makes the associated NLP problem somewhat less complex than full understanding.

3 Prior Work on Associating Documents to Concept Maps

The combined top-down/bottom-up approach contrasts with most prior research on automatic methods to form associations between documents and concept maps, which address the problem exclusively top-down. For example, recent research has applied information retrieval solutions to proactively search the Web (Leake *et al*. 2004) and to search specific document libraries (Reichherzer & Leake 2006a) for resources that are topically related to a concept map under development. However, these solutions aim to provide assistance to users during concept map construction, so the only information that these approaches use from documents is their keywords matching the labels in the target concept map.

Some prior work has instead explored bottom-up approaches, attempting to construct concept maps (or similar representations) automatically from text, but ignoring the information that is available in the possible target concept map knowledge model. Valerio, Leake & Cañas (2007) and Valerio & Leake (2006) apply information extraction techniques to produce a normalized list of concepts, for which labels are assigned by selecting the shortest available label extracted from the document. Alves, Pereira, & Cardoso (2001) use WordNet to extract a hierarchy of nouns from a document and build a list of concepts, followed by iterations of user feedback to identify relationships between pairs of concepts and assign initial labels to relations. Another alternative focuses on word sense disambiguation, using the meaning of nouns and verbs to search for Noun-Verb-Noun structures in the sentences (Rajaraman & Tan 2002). One step towards a more combined approach relies on a predefined list of domain-specific concepts provided by an expert but only considers two concepts to be related if they occur in the same sentence (Clariana & Koul 2004).

4 Overview of the Approach

We address the classification problem starting with a predefined set of concept maps, which constitute the classes. We assume that this set of concept maps will have been generated by hand, by experts or other users, and that the number of concept maps is comparatively small. However, most proposed processing steps are relatively efficient, and some intermediate calculations on the concept map collection can be done offline and stored along with the corresponding map to increase efficiency. In particular, the calculation of the importance of concepts in a map can be executed in this fashion.

The task is to assign each document to the most relevant member of the set of concept maps. Our approach begins by generating sets of indices for each document, each one generated in the context of a different target concept map, in order to bias index generation towards maximizing similarity with the target map. The concept map whose index best matches the corresponding document index is selected as the classification.

More specifically, to associate documents with concept maps, the system takes as input a document and a set *S* of concept maps (called *context concept maps*). For each concept map in this set, the system applies the index generation algorithm (described in a following section) to produce a set of *concept map indices* from the document, in context of that map. This produces n slightly different sets of concept map fragments as the document index. Each document index *index*(*D,C*) makes the concept labels in the index as similar as possible to the labels in the corresponding context concept map *C*, and the concept map most similar to the index is selected. Thus:

$$Class(D,S) = \arg\max_{C \in S} Sim(index(D,C),C)$$

Our approach differs from traditional document categorization algorithms (Sebastiani 2002) in two ways:

1. *Concept map fragments as indices*: Our document representation is based on concept map fragments as indices. The significance of this approach is that these concept map fragments include structural information about concept relationships, which we expect to provide a more accurate representation of its content compared to a set of weighted keywords, and also to enable more effective matching when comparing documents to concept maps, which themselves are structured.
2. *Focus on finding the most similar classification*: Our aim is not to make a boolean decision about whether a document fits a specific fixed category, but rather to identify the most similar element in the search space. This method is in the spirit of K-nearest-neighbor and case-based reasoning, which take a lazy learning approach to categorization. This approach is suitable, for example, when automatically associating documents to the most relevant knowledge model, for a user to make the final determination of whether to add them to the knowledge model.

5 Automatic Generation of a Concept Map Index

Many natural language processing techniques exist for exploiting the information contained on the structure of sentences and phrases of documents (e.g., Harabagiu *et al*. 2005; Alves, Pereira, & Cardoso 2001). For our task of associating documents to existing concept maps, many of the same methods are relevant and could be applied to refine the process. Here we focus on the characteristics of the process which are specific to the task of mapping documents to concept maps.

Our approach revises our previous bottom-up model of concept map generation (Valerio, Leake, & Cañas 2007). That constructed concept maps based solely on the concepts and linking phrases found in the input document. Our central addition is in the *Concept labeling* step, which now assigns concept labels based on the existing labels from an input concept map, to provide a context to bias the map generation. In this way, if a relevant target concept map is known, the labels of the new map may be biased towards the vocabulary used in the target map.

The algorithm used for this task is summarized in Figure 2. The algorithm steps are described below.

Parsing: The document is first preprocessed by a sentence boundary detection algorithm based on regular expressions, followed by a part-of-speech tagger. Each sentence is then processed by a partial parser to recognize sequences of words corresponding to concepts and linking phrases, using the part-of-speech tags as input. The parsing approach is a modification of Abney's partial parser (Abney 1996) as detailed in (Valerio, Leake, & Cañas 2007).

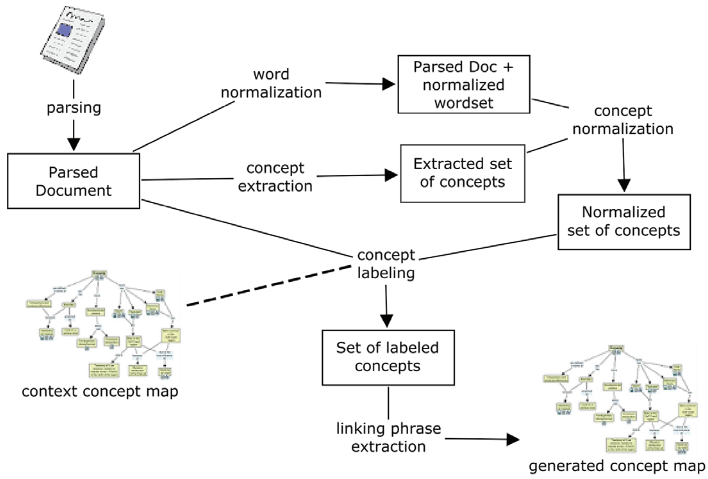

Figure 2. Procedure to construct a concept map index automatically from a document.

Word normalization: Documents contain morphological variations of words that refer to the same entity, and may use multiple synonyms. The word normalization step splits words into disjoint equivalence classes, using a lemmatizer to find the root of the words (e.g., the root word of "realizing" is "realize"), and a part-of-speech tagger and WordNet (Fellbaum 1998) to find synonymy relations. Once the algorithm identifies the word equivalences, it tags each word with its class, for use in comparing words in later steps.

Concept extraction: This step simply selects the concepts discovered during parsing.

Concept normalization: The sentence chunks corresponding to concept labels may have superficial differences despite some of them referring to the same concept. The normalization step implements a simple solution for co-reference resolution. Two concept labels are considered the same if all nouns and adjectives in either one are contained in the other, considering the classes produced during the word normalization step. This procedure is applied to resolve named entity co-references as well. The primary challenge for this step is to find co-references across large text spans, because for our application these cannot be limited to references within sentences or paragraphs.

Concept labeling: Once the set of equivalent concepts is produced by the previous step, they are assigned a unique label. The input context concept map is used for this purpose. All concept labels from the context concept map are extracted and compared with the sets of normalized concepts, using the procedure described in the previous step. If there is a match, the set of concepts is assigned the label from the context concept map. Otherwise, it is assigned the shortest label extracted from the document. For example, the normalized concept set: {"line of thunderstorms", "thunderstorm activity"} is labeled as "thunderstorms", instead of "thunderstorm activity" making it more similar to the context concept map, therefore augmenting the chances of being classified in this category.

Linking phrase extraction: Using the parsed sentences and normalized concepts, the sentences in the document are searched for linking phrases that appear between two concepts. These three chunks are used to generate a proposition, as we presume that the phrases show relations between concepts. For example, "thunderstorms" –are frequent in→ "the gulf coast".

Concept map generation: The information from the extracted concepts and linking phrases, in the form of propositions, is used to construct a graphical representation of the concept map. Although this representation is not required to construct the concept map index from the document, it enables the results to be displayed by existing tools for concept map construction. Finally, after integration of all propositions, the map can contain node strings (sequences of nodes that are not connected to other segments) and these are replaced by a single node whose label is the concatenation of the node string labels. This replacement has minor effects on the individual node weight during concept map index comparison.

Figure 3 shows an example of concept map indices generated from a document by the system. The top concept map is an input context map used as context for index generation. The bottom left map is an index concept map generated by the previous version of the algorithm without the context-based concept-labeling step, and the bottom right map is the index generated by the new algorithm. The highlighted concepts correspond to concepts that were matched during the labeling step and were replaced. The document passage from which the indices were generated is shown at the bottom of the figure.

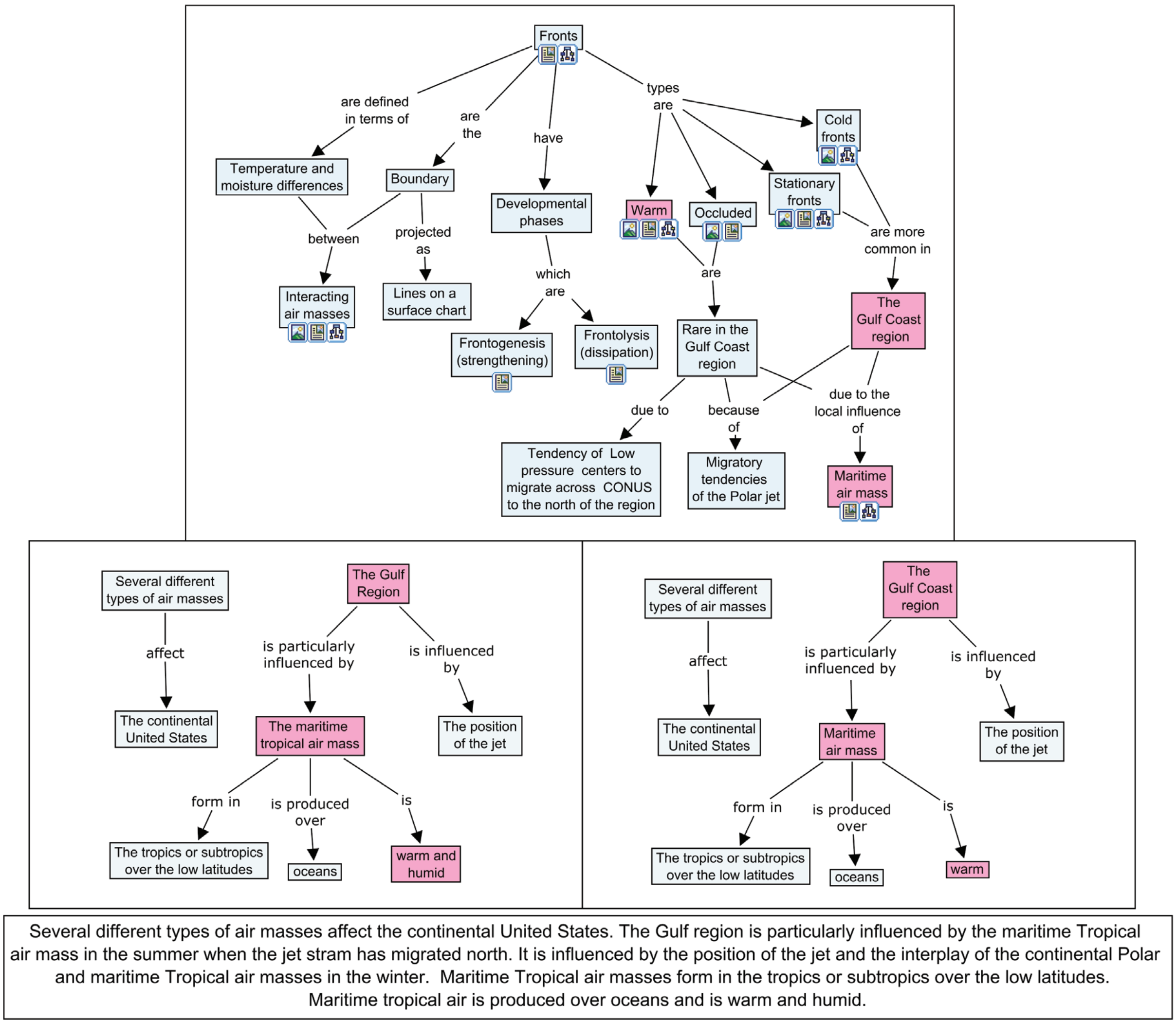

Figure 3. Example of a document converted to a concept map (top map is from STORM-LK (Hoffman *et al.* 2001)).

6 Concept Map Similarity Assessment

To identify relevant concept maps, the index concept maps are compared with the corresponding context concept map using cosine similarity (Baeza-Yates & Ribeiro-Neto 1999) and a vector-model representation of concept maps (Leake *et al*. 2003). The concept map vectors are constructed as in (Valerio, Leake, & Cañas 2007), using the Hub-Authority-Root-Distance (HARD) model (Reichherzer & Leake 2006b) to estimate concept importance based on structural features, each concept is assigned a weight based on its *authority* value (increasing with number of incoming connections from hubs), *hub* value (increasing with number of outgoing connections to authorities), and *upper node* value (shortest distance to root concept). Next, individual keywords are assigned weights according to their frequency and the weight of concepts in which they appear. Each keyword defines a dimension in the concept map vector.

The weight $w(i)$ of concept i according to the HARD model is:

$$w(i) = \phi \cdot h(i) + \psi \cdot a(i) + \gamma \cdot u(i)$$

where $h(i)$, $a(i)$, and $u(i)$ are the authority, hub, and upper node values for i, described in detail in (Cañas, Leake, & Maguitman 2001).

In our experiments, the parameters are set to $\phi = 0, \psi = 2.235, \gamma = 1.764$, which were previously found to best fit the model for experimental user data (Leake, Maguitman & Reichherzer 2004). The weight $w(j)$ of keyword j is the sum of the concept weights multiplied by the frequency of the keyword in each concept.

$$w(j) = \sum_{i \in concepts} frequency(i,j) \cdot w(i)$$

Keywords are normalized with a lemmatizer to prevent mismatches due to morphological variations and also tagged with part-of-speech to reduce noise.

6.1 Experimental setup

Our experiment tests the ability of the algorithm to associate an input document to the most relevant maps in a collection of concept maps constructed by experts. The test data for the evaluation is a set of existing knowledge models containing a number of concept maps annotated with topically related documents, which have been used previously as "gold standard" concept maps for evaluating concept map-document associations. The knowledge models from Mars 2001 (Briggs *et al*. 2004) and STORM-LK (Hoffman *et al*. 2001) contain a total of 80 concept maps and 131 different documents already linked to the concept maps. It is possible for a document to be associated with more than one concept map. The evaluation is based on a match between the concept maps identified by the system as the most relevant and the original concept map annotations, measuring the ability of the procedure to find the original associations.

To perform the test, all documents are separated from the concept maps. Next, each of the documents is processed individually with no prior knowledge about the concept maps to which it was originally linked used in this processing. As described in the previous section, for each document the concept map generation process is repeated with all 80 concept maps separately, producing 80 slightly different concept map indices differing on their concept labels. The system then compares the produced index concept maps with the corresponding concept maps in the knowledge model using the similarity measure describe above. Next, the concept map indices are sorted in descending order by their similarity value to the maps used as context for generating them, with the similarity measure used to judge relevance.

One goal of this evaluation is to determine the precision and recall achieved by the system when different cutoffs are applied to select the relevant concept maps from the sorted list. In our case, the cutoffs range from 1 to 5. Cutoff = 2 means that the two most similar concept maps are attached to the document. An attachment is considered successful if the document is correctly associated with a concept map originally containing it.

6.2 Experimental results

The algorithm performance was compared to the algorithm presented in (Valerio, Leake, & Cañas 2007) and to a baseline algorithm that constructs its document vector representation solely based on keyword frequency. The latter illustrates the performance in the absence of structural information.

Figure 4 shows the results of the evaluation. The new algorithm showed an average precision increase of 14% compared to the previous algorithm that does not use the target concept map labels, and 27% compared to the baseline. We also calculated the F1 measure (harmonic mean of precision/recall) when only the most similar concept is associated with the document (cutoff = 1). In this case, the proposed algorithm also outperformed the other methods by similar margins. This indicates that the precision was increased without degrading recall.

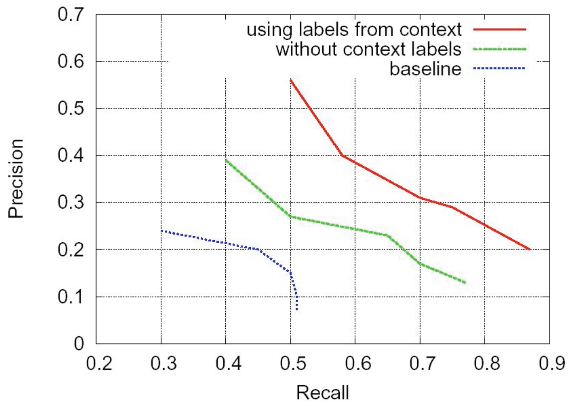

Figure 4. Precision/Recall plot for document classification with the three methods.

The improvement when a concept map index is constructed using the concept labels from a target concept map suggests the value of using the context of the target concept maps to refine the automatic concept map generation procedure, indicating that the information obtained from the concept map context is meaningful. These results also indicate a significant improvement of the results compared to the keyword-based algorithm reaffirming that the structure of the generated concept map gives valuable information during the document classification task.

7 Summary and future work

This paper presented a top-down/bottom-up algorithm to extract information from documents to construct concept map indices automatically, using target concept maps as context to refine the assignment of concept labels. The addition of top-down information resulted in a significant performance improvement compared to the previous bottom-up only approach, when using the indices for a document classification task. These results suggest the promise of this approach to generating concept-map indices from documents, taking advantage of existing natural language processing techniques to extract information efficiently from documents and at the same time using existing concept map knowledge models to guide the construction process as a higher-level semantic information source.

The ultimate goal of our project is to develop intelligent user interfaces to assist during document understanding and contextualization tasks. For this work, we intend to further refine the concept normalization step of the conversion procedure to produce better quality concept map indices and to also refine and evaluate the linking phrase extraction step, which we foresee as an interesting and challenging task.

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AUTOMATIC CLASSIFICATION OF CONCEPT MAPS BASED ON A TOPOLOGICAL TAXONOMY AND ITS APPLICATION TO STUDYING FEATURES OF HUMAN-BUILT MAPS

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Abstract. The flexibility of concept mapping enables users to construct a wide range of maps for a given domain. This variation raises the question of what constitute "good" concept maps. This paper contributes towards answering this question by presenting the development and evaluation of a tool for automatic classification of concept maps based on a topological taxonomy. In addition to showing successful demonstrations of the tool's ability to distinguish novice and expert maps, the paper shows the usefulness of the tool for understanding the types of features that occur in human-generated concept maps.

1 Introduction

Concept maps are an explicit graphical representation of a human's understanding of a domain of knowledge. Concept maps represent this understanding by means of a two-dimensional network in which nodes correspond to concepts and links correspond to concept relationships. In a concept map, *concepts* are the labels used to refer to objects or events and *linking phrases* (the text on the links) are usually verbs (Novak & Gowin, 1984). Given that each person's understanding of a domain is different, even if people construct concept maps on the same topic, the maps constructed by every individual are different, reflecting their personal knowledge structures. Concept maps differ from other graphical knowledge representation schemes in the freedom map builders have when selecting concepts and linking phrases, which are limited only by the constraint that concepts linked by a linking phrase should form a propositional sentence, a claim that "makes sense" when read separately from the map. This freedom results in further variation among the maps constructed on a same topic. The resulting flexibility is commonly regarded as an advantage of concept mapping for use in many fields, such as education, in which the map reflects what the student knows, and for representing the knowledge of experts, in which the map is used to represent the idiosyncrasies of each expert.

The freedom for concept map builders results in a variety of concept maps. This variety has at times considered by some to be a "problem." Computer scientists, for example, often complain about the lack of formality in concept maps, which makes it difficult for computer programs to "process" concept maps, where "processing" could be referring to performing inference on the knowledge expressed on the map, making some kind of decision based on the map, or trying to automatically rate or compare maps. To facilitate such processing, many researchers and practitioners restrict the list of concepts and/or linking phrases from which the map builder can select, resulting in varying degrees of "formality" in the resulting types of maps. Accepting that the flexibility provided by concept mapping in the selection of concepts and linking phrases makes it difficult to perform fully automatic analysis of concept maps, our research efforts have been aimed at the construction of tools that aide the user in all facets of interaction with electronic concept maps, including tools for concept map construction (Cañas, Hill et al., 2004), searching the Web using concept maps (Leake et al., 2004), suggesting concepts during map building (Cañas, Carvalho et al., 2004), categorizing documents based on concept maps (Valerio, Leake, & Cañas, 2007), among others.

A common issue within the concept mapping community is how to "assess" concept maps. Despite the variety of concept maps that arise from the differences among map builders, some maps can be considered "better" than others, based on a variety of criteria. One concept map could show a "deeper understanding" of a topic than another, perhaps reflecting that the first was constructed by an expert and the second by a novice. One map could be considered by some to be "easier to read" than another map on the same topic. Among the features that can be used to assess the quality of a concept map, we can distinguish between topological features (e.g. hierarchical structure, linking phrases, number links into and out of concepts, etc.), and semantic features (are the propositions correct? how expressive are the linking phrases? is the focus question answered by the concept map?). Of course, the semantic content is always more important than the topological structure, but just as in the English language a well structured sentence is considered to be better written than a badly structured sentence, even if their content is the same, a "well structured" concept map is considered better than a badly structured map, even if their contents are "equivalent." There seems to be some agreement among concept mapping "experts" regarding some of the characteristics of a "well structured" concept map, even they only get a "glance" at them (Carvajal, Cañas, Carballeda, & Hurtado, 2006).

In this paper we report on an effort to automatically classify concept maps based on topological features. Clearly a classification based on topological features is not the automatic assessment rubric that teachers often look for to automatically assess their students' concept maps; we are certainly not attempting to assign an "absolute score" for a map. This work makes three primary contributions: (1) the development and validation of a tool for automatic classification of maps based on a topological taxonomy, (2) development and validation of models of well-constructed concept maps that can be used to facilitate automatic construction of concept maps (Valerio et al., 2007), and (3) the refinement of previous models used for automatic concept mapping support, e.g. the concept Suggester (Cañas, Carvalho et al., 2004). The tool can integrate a broader environment to study the evolution of individual student concept maps in time, to determine how these maps change as the student progresses in both understanding the subject matter and developing skills for constructing concept maps.

2 Topological taxonomy classification and feature annotations

Recent research studies the topological properties of concept maps. (Novak & Cañas, 2006) describe guidelines for concept map construction and identify a list of features that well constructed maps commonly have. Further study resulted in the development of a topological taxonomy for concept maps (Cañas, Novak et al., 2006) based on these features. The taxonomy is intended as a tool to estimate the quality of human-made concept maps based on their structural complexity. It has been successfully used as an evaluation tool for "Proyecto Conéctate al Conocimiento" in Panama (Tarté, 2006) as part of a larger scheme to measure the impact of concept mapping in education. In the context of automatic support of concept mapping tasks, other structural features were identified: High-value concepts in maps, used for searching the Web (Leake et al., 2004), and concept descriptors and discriminators used to describe the topic of a map (Maguitman, 2005), and to associate document libraries to concepts (Reichherzer & Leake, 2006).

Based on the topological taxonomy and other features used in earlier research, we developed a set of algorithms to automatically classify electronic concept maps by their topological category and make annotations of structural features. As described in Section 5, the tools can be used to efficiently annotate large collections of human-built concept maps and assist on quantitative analyses of their structure. If accurate, these tools can also be used to support other concept mapping tasks, for example aiding users by suggesting structural changes to a map under construction.

This section describes the feature annotation algorithms in detail. Most algorithms are based on combinations of previously published work, with some notation changed to have a uniform description. The algorithms make two kinds of annotations: map level and node level annotations. The annotations could be absolute counts (e.g., the total number of concepts) or scores (e.g., hub and authority scores of nodes in the concept map graph). All score annotations are normalized in the range [0, 1].

2.1 Topological taxonomy of maps

The topological taxonomy (Cañas, Novak et al., 2006; Miller, 2008) classifies concept maps into seven levels of increasing structural complexity. In the taxonomy, a map is represented by five features known to be good descriptors of concept map structure: the existence of hierarchical structure, size of concept labels, presence of linking phrases, number of branching points, and number of cross links. Values for these features determine the level of complexity.

To determine the topological class of a map, our automatic topological classifier executes the following procedure: In an iterative process which starts from Level 0, if the map belongs to Level *N*, check if it belongs to Level *N+1* until the topmost Level 6 is reached. If during the sequential checking the map fails one of the conditions of Level *N*, then classify the map as Level *N-1*. Table 1 describes the conditions evaluated by the classifier at each level of the taxonomy. As described in later sections, the tool could be used to analyze large sets of maps. Because some of these maps might be under construction or too small for analysis, consequently not satisfying conditions for any level, for completeness the table introduces a Level -1 to label to such maps.

2.2 Root concept

Structurally, a concept map is a directed graph of concept and linking phrase nodes. The root concept of a map is defined as "the most general and most inclusive concept" (Novak & Cañas, 2006) and is considered the head of the concept map hierarchy, from which all other nodes can be reached though some path. The root is commonly found in the topmost vertical position.

Previous work on automatic concept map processing describes different methods to discover the root concept. In Cañas *et al.* (2001) the root is the concept with the highest upper node score; a measure to characterize concepts that appear in the top of a tree hierarchy. For most concept maps, the upper node score (described later on) can be used as an accurate estimator for the root concept, but due to its recursive definition it assigns the root a very low value when a concept in the lower levels of the tree has a cross link to the root. Another definition of root concept is used in Reichherzer & Leake (2006), where the root is the node with the highest value of $\#outgoing\_links - \#incomng\_links$, however it assigns the root using only limited information about the structure of the map. These definitions are independent of two features that can help find the root more accurately: the "outreach" of the concept (the number of concepts that can be reached though some path starting on the node) and the relative vertical position of the concept.

Level #	Conditions by level as indicated in Cañas, Novak et al. (2006)	Conditions evaluated by to classify concept map *M*, which has concept *c* and linking phrase *l* the as nodes of *M*.
Level -1	No conditions	(default)
Level 0	At least 4 connected concepts	$\left\|\{c : concept\}\right\| \geq 4$
	Mostly long concept labels	(default)
	Empty linking-phrases	(default)
	0 to 1 branching points	(default)
Level 1	More concepts than long concept labels	$\left\|\{c : concept \mid labelSize(c) < 12\}\right\| \geq \left\|\{c : concept\}\right\| / 2$
	Half or more missing linking-phrases	(default)
	0 to 1 branching points	(default)
Level 2	More concepts than long concept labels	(checked at Level 1)
	Less than half missing linking-phrases	$\left\|\{l : linkingPhrase \mid labelSize(l) > 0\}\right\| \geq \left\|\{l : linkingPhrase\}\right\| / 2$
	At least 2 branching points	$\left\|branchingPoints(M)\right\| \geq 2$
Level 3	No long concept labels	$\forall c : concept, labelSize(c) < 12$
	No linking-phrases missing	$\forall l : linkingPhrase, labelSize(l) > 0$
	At least 3 branching points	$\left\|branchingPoints(M)\right\| \geq 3$
	Less than 3 hierarchy levels	(default)
Level 4	No long concept labels	(checked at Level 3)
	No linking-phrases missing	(checked at Level 3)
	At least 5 branching points	$\left\|branchingPoints(M)\right\| \geq 5$
	At least 3 hierarchy levels	$\exists c : concept, depth(c, M) > 3$
Level 5	No long concept labels	(checked at Level 3)
	No linking-phrases missing	(checked at Level 3)
	At least 5 branching points	(checked at Level 4)
	At least 3 hierarchy levels	(checked at Level 4)
	At least 1 cross-link	$\left\|crossLinks(M)\right\| \geq 1$
Level 6	No long concept labels	(checked at Level 3)
	No linking-phrases missing	(checked at Level 3)
	At least 7 branching points	$\left\|branchingPoints(M)\right\| \geq 7$
	At least 3 hierarchy levels	(checked at Level 4)
	At least 3 cross-links	$\left\|crossLinks(M)\right\| \geq 3$
Conditions labeled with (default) are met if the map fails a condition of a following level. Conditions labeled with (checked at Level N) are revised at a previous level.		

Table 1: Required conditions for the levels of the topology classifier.

In the approach of developed in this paper, the root concept score is defined as a linear combination of the four features mentioned above. The root concept of a map *M* is:

$$root(M) = \arg\max_{c \in M}\left(w_U \cdot upperNodeScore(c) + w_O \cdot outgoingScore(c) + w_R \cdot outreachScore(c) + w_P \cdot verticalPositionScore(c)\right)$$

Currently, the values of w_U, w_O, w_R, w_P are 0.1, 0.16, 0.37, 0.37 respectively, which are the best-fit parameters for a small training set of concept maps manually marked with the root concept.

2.3 Cross-links and Cycles in the concept map graph

Safayeni *et al*. (2005) studied the presence of cross-links and cycles in concept maps as indicators of a rich structure and examined their importance in educational settings. According to Novak & Cañas (2006), a cross link is "a link between concepts in different segments or domains of the concept map." For the purposes of our algorithm, a link between two concepts is a cross link if they belong to two different branches of the concept map hierarchy, defined as follows. Concepts A and B are in two different branches if the shortest path from A to the root node $\langle Root,\ldots,A\rangle$ does not share more than K nodes with the path of B $\langle Root,\ldots,B\rangle$; in other words, the closest common ancestor of A and B is at least at distance K. This guarantees enough separation between the two concepts for which a cross link is found. In the algorithm implementation K was set to 5.

A cycle in a concept map is as defined for directed graphs: it is a path of size more than 1 that starts and ends with the same node. The definition is simple, but an algorithm to find all cycles in an arbitrary concept map can be computationally expensive for large graphs. Fortunately, concept map graphs are relatively small.

2.4 Hub, Authority, and Upper concepts

The definition of hub, authority and upper concepts was introduced in Cañas, Leake, & Maguitman (2001) in the context of automatic support for human concept mapping tasks. These serve as features to help find high value concepts in a concept map graph, which can be used in interactive concept suggesters (Cañas, Carvalho *et al.*, 2004) or automatic identification of terms that describe the topic of a concept map (Maguitman, 2005).

We are interested in calculating the scores for concept nodes only, so we take the full concept map graph $G_M = (V_M, E_M)$ and define a new graph G_C – the concept-to-concept graph of map M – as:

$$G_C = (V_C, E_C),\ V_C = \{c : concept, c \in V_M\},\ \text{and } E_C = \{(c_1, c_2) \mid l : linkingPhrase, l \in V_M, (c_1, l) \in E_M, (l, c_2) \in E_M\}.$$

The hub and authority scores for concepts in the graph G_C are calculated by a mutually recursive definition, originally described in Kleinberg (1999):

$$hubScore(c_1) = \sum_{(c_1,c_2)\in V_C} authorityScore(c_2) \text{ and } authorityScore(c_1) = \sum_{(c_2,c_1)\in V_C} hubScore(c_1)$$

maintaining the constant $\sum_{c\in E_C} hubScore(c)^2 = \sum_{c\in E_C} authorityScore(c)^2 = 1$

The upper node score for the concepts in graph G_C is calculated by a recursive definition as well:

$$upperScore(c_1) = 1 \; if \; \neg\exists (c_2, c_1) \in V_C \; and \sum_{(c_2,c_1)\in V_C} upperScore(c_2) \; otherwise.$$

2.5 Lower level features

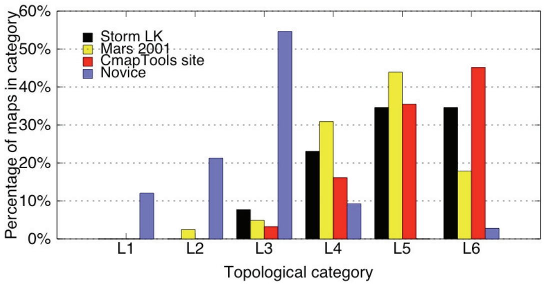
The features described previously are defined in terms of simpler lower level characteristics defined as follows:

- **Node label size:** The size of a node label is the number of terms separated by whitespace characters. Some maps have concepts that are connected directly without a linking phrase. In this case, an artificial linking phrase is created with an empty label.
- **Concept depth value:** The depth of a concept in a map is the length of the shortest path from the root concept to the node. The depth of the root concept is 0.
- **Branching points in a map:** A branching point is a concept or linking phrase node with more than one outgoing link.
- **Outgoing reach concept score:** The outgoing reach score of a concept c is based on the number of concepts that can be reached by walking the map graph exhaustively starting from c. The scores of all concepts in a map are normalized in the range [0,1].
- **Outgoing concept score:** Measures the local output connectivity of a concept. The outgoing score of a concept is the normalized value of $\#outgoing\_links - \#incomng\_links$.
- **Vertical position concept score:** Assigns a linear score based on the relative vertical position of the concept in the concept map layout; giving the topmost concept a score of 1 and the bottommost position a 0.
- **Number of concept map resources:** Electronic concept maps can be annotated with multimedia resources and with topically related concept maps. These attached resources could be: concept maps, documents, images, or videos. A simple count is taken for each type.

3 Validation of the automatic topological taxonomy classifier

The topological taxonomy classifier was used to segment a collection of human made concept maps, to study the characteristics of maps on each topology level. In order to assess the classifier's performance, an independent categorization of the maps was needed. Consequently, the algorithm was validated using a preclassified set of concept maps as testing set. The set contained maps of two major categories: (1) expert concept maps: 180 maps built by concept mapping experts; these include STORM-LK (Hoffman, Coffey, Ford, & Carnot, 2001), Mars 2001 (Briggs et al., 2004), and the concept maps in the CmapTools website[1]; and (2) novice concept maps: 108 maps selected manually from a public repository showing different construction deficiencies as described in Novak & Cañas (2006).

Table 2 presents the result for the classification by the topology classifier. Ideally, all expert concept maps would be classified in the higher levels of the hierarchy and all novice maps in the lower levels. The results show that 93% of the expert maps were classified in Levels 4, 5 and 6, while 88% of novice maps were classified in levels 1, 2 and 3, confirming the accuracy of the classifier. The maps on the "expert" set were not manually inspected to verify that all belong to the highest levels of the taxonomy, therefore some noise may be present in this set which can be consistent with relatively few misclassifications.



	Storm LK		Mars 2001		CmapTools site		Novice	
	number	%	number	%	number	%	number	%
Level-1	0	0%	0	0%	0	0%	0	0%
Level 0	0	0%	0	0%	0	0%	0	0%
Level 1	0	0%	0	0%	0	0%	13	12%
Level 2	0	0%	3	2%	0	0%	23	21%
Level 3	2	8%	6	5%	1	3%	59	55%
Level 4	6	23%	38	31%	5	16%	10	9%
Level 5	9	35%	54	44%	11	35%	0	0%
Level 6	9	35%	22	18%	14	45%	3	3%

Table 2: Performance of taxonomy classifier on the test set.

The topological taxonomy definition described in Cañas, Novak *et al.* (2006) considers mostly structural characteristics of concept maps to decide their levels. It is unclear if structural features alone are sufficient to achieve accurate classification. Content features could also be explored as additional information about the map to improve the classification performance. Some of these features have been successfully used for other concept mapping tasks, for example to find good descriptor and discriminator terms for the topic of a map (Maguitman, 2005). A semantic rubric has been developed as part of the Conéctate project, which could be evaluated for incorporation into this tool (Miller & Cañas, 2008).

4 Selection, cleanup, and processing of human built concept maps

The second major goal of this work is to analyze the composition of human-made concept maps through an empirical study. Three main sources of concept maps were selected: (1) the 180 expert knowledge maps used during the validation procedure described in Section 3, (2) 8018 maps from the public CmapServer[2] (Cañas, Hill et al., 2004) *IHMC Public Cmaps (3)*'s *Users* directory, and (3) 13,287 maps from the public *Conéctate Público (Panama)* public CmapServer, which mostly correspond to the "Who Am I?" maps of the project (Sánchez et al., 2008). The maps were crawled from the CmapServers using KEA (Cañas, Hill et al., 2006) and downloaded into a local repository to simplify their processing.

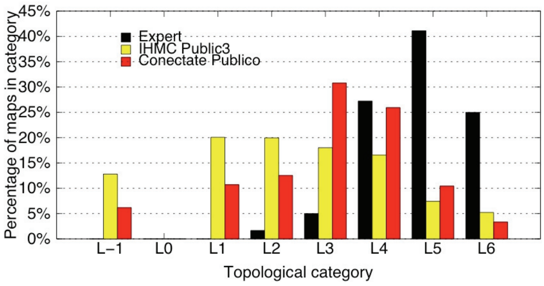
Before processing, each map was cleaned to remove concepts that were not connected to the main map. These floating concepts are frequently used to record the focus question of the map and are not considered part of the concept map itself. Occasionally, the author of the map can introduce noise to the concept map graph during map generation, especially by accidentally reversing the direction a link between concepts. These errors are difficult to detect and introduce noise that could affect the performance of the algorithms.

After the clean up step, each map is processed individually and all annotations described in Section 2 are made. Finally, the maps are split by levels using the topological taxonomy classifier and grouped by level to gather the aggregated information.

[1] These knowledge models can be accessed at: http://cmapskm.ihmc.us/servlet/SBReadResourceServlet?rid=1103742096094_178662418_7950&partName=htmltext, http://cmex.ihmc.us, and http://cmap.ihmc.us.
[2] A "public" CmapServer is one on which anyone can store concept maps using the CmapTools client, and therefore there is no 'control' or filter on the quality or type of maps stored. The two public CmapServers used in this study can be accessed at: http://cmapspublic3.ihmc.us, and http://cmapspublico.conectate.edu.pa.

5 Characteristics of human built concept maps

This section presents the results of processing maps aggregated by levels of the topological taxonomy. Table 3 presents the distribution of concept maps into topology categories grouped by source. As described in Section 4, the “Expert” category includes all maps from “STORM-LK”, “Mars 2001”, and “CmapTools documentation maps”. We observe that most expert maps are classified in the high level of the taxonomy. Also, the maps from the “Conéctate” project have substantially better classifications than the maps from *IHMC Public Cmaps (3)/Users* server and this result could reflect the impact of the concept mapping workshops in Conéctate.

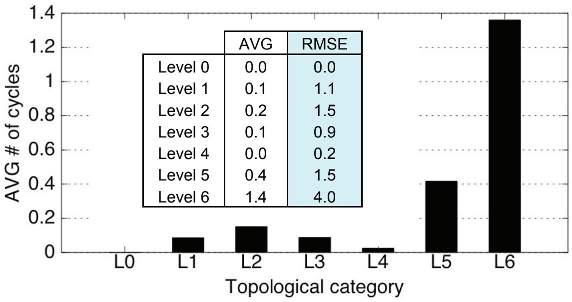


	Expert		IHMC Public3		Conéctate Público	
	number	%	number	%	number	%
Level-1	0	0%	1026	13%	823	6%
Level 0	0	0%	0	0%	0	0%
Level 1	0	0%	1609	20%	1424	11%
Level 2	3	2%	1600	20%	1668	13%
Level 3	9	5%	1444	18%	4093	31%
Level 4	49	27%	1327	17%	3447	26%
Level 5	74	41%	594	7%	1388	10%
Level 6	45	25%	418	5%	444	3%

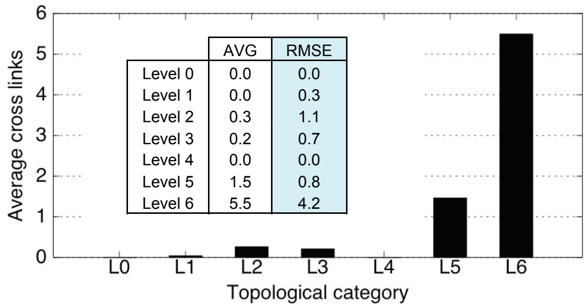
Table 3: Distribution of maps in taxonomy levels grouped by source

The following tables present variables from maps correlated with their topological taxonomy level. These were obtained by the annotations described in Section 2. Each variable is represented by its average (AVG) normalized by the size of the map and the root mean square error (RMSE) is reported as the standard deviation. All maps from the three sources were combined to get information about the aggregated data.

Table 4 presents the number of cycles and crosslinks by category, where the Levels 5 and 6 show a higher number of these features. The variance of the number of cycles at Level 6 is surprisingly high possibly indicating the existence of a small number of maps with very high connectivity.



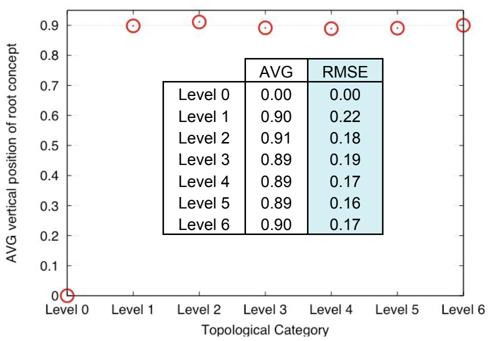
	AVG	RMSE
Level 0	0.0	0.0
Level 1	0.1	1.1
Level 2	0.2	1.5
Level 3	0.1	0.9
Level 4	0.0	0.2
Level 5	0.4	1.5
Level 6	1.4	4.0



	AVG	RMSE
Level 0	0.0	0.0
Level 1	0.0	0.3
Level 2	0.3	1.1
Level 3	0.2	0.7
Level 4	0.0	0.0
Level 5	1.5	0.8
Level 6	5.5	4.2

Table 4: Average number of cycles and crosslinks per category.

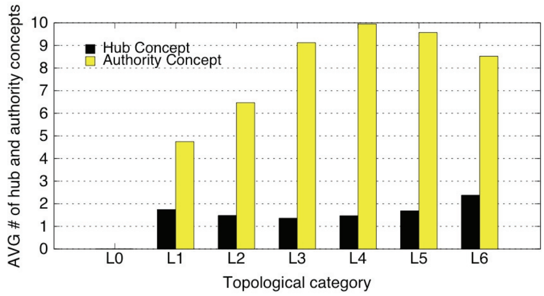
Table 5 shows the average vertical position of the root node in the concept map layout. It shows that regardless of the level it is consistently positioned in the topmost part of the map.



	AVG	RMSE
Level 0	0.00	0.00
Level 1	0.90	0.22
Level 2	0.91	0.18
Level 3	0.89	0.19
Level 4	0.89	0.17
Level 5	0.89	0.16
Level 6	0.90	0.17

Table 5: Average vertical position of the root node in a map layout.

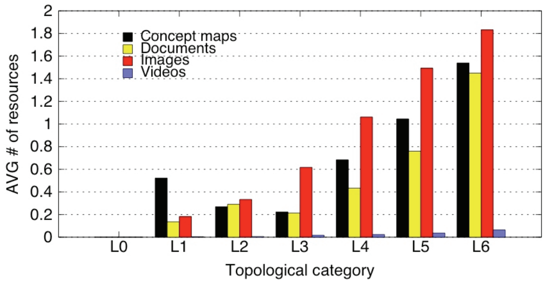
Table 6 shows the distribution of hub and authority concepts. The number of authority nodes is consistently higher than the hub nodes, reflecting the hierarchical structure of concept maps. Also, the proportion of authorities to hubs decreases on Levels 5 and 6, due to cycles and crosslinks from the lower nodes of the map to higher nodes.



	# hub concepts		# authority concepts	
	AVG	RMSE	AVG	RMSE
Level 0	0.0	0.0	0.0	0.0
Level 1	1.7	2.3	4.7	3.6
Level 2	1.5	1.3	6.5	4.0
Level 3	1.4	1.2	9.1	5.5
Level 4	1.5	1.3	9.9	5.6
Level 5	1.7	1.4	9.6	5.7
Level 6	2.4	2.0	8.5	5.4

Table 6: Distribution of hub and authority nodes by category.

Table 7 shows the distribution of resources per category, which illustrate the increasing number of attached resources as the structure of the map improves. This indicates that authors of more structurally refined maps also refine their maps with more resources and suggest that these maps may be part of a more complex knowledge model.



	Concept maps		Documents		Images		Videos	
	AVG	RMSE	AVG	RMSE	AVG	RMSE	AVG	RMSE
Level 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Level 1	0.5	8.2	0.1	1.2	0.2	1.2	0.0	0.1
Level 2	0.3	1.3	0.3	2.5	0.3	1.6	0.0	0.1
Level 3	0.2	1.2	0.2	1.6	0.6	2.0	0.0	0.3
Level 4	0.7	3.5	0.4	2.7	1.1	3.1	0.0	0.3
Level 5	1.0	3.3	0.8	3.4	1.5	3.4	0.0	0.5
Level 6	1.5	4.9	1.4	6.1	1.8	5.0	0.1	0.6

Table 7: Number of attached resources by category

6 Summary and Future work

In this paper, we present the construction and validation of an automatic classifier of concept maps based on its topology along with a suite of annotators to help analyze concept map topological features. The classifier and annotators were applied to a collection of human built concept maps to identify the structural composition of real-life concept maps.

Further work needs to be done to refine the existing methods to go beyond structural information, bringing in semantic considerations to extend existing models of well constructed concept maps. Also, we foresee the use of the implemented classifier as the basis for a tool to study the evolution of individual concept maps in time by comparing a sequence of snapshots in time through periodic crawling.

In addition, starting from a collection of concept maps annotated with information on concept map quality, the annotators could be used as the basis for a bottom-up analysis of which features are most important for assessing concept map quality, potentially providing more refined assessment methods.

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BUILDING MEANINGFUL LEARNING THROUGH A WEB SEARCH AND CONCEPT MAPS

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Abstract. What is the situation in which a teacher has to operate every day?

- Our students highlight a great tension because of relationship problems;
- It's more and more difficult to motivate students as for Science is concerned;
- Students "learn" what teachers teach them, but they are not able to transfer their learning into a real life context;
- The research OCSE, PISA 2003 and 2006, about both scientific areas and problem solving, points out a deficiency in Italian students' base abilities and their low motivation for scientific studies.

"Paradoxically bad marks in Science, wrote the French professor Andrè Giordan (University of Geneve), are not the worst data of the PISA survey. What must worry us is something that the PISA did not measure: the feeling of boredom and the lack of interest in Science, which students show while talking about it. These subjects, as they are taught nowadays, discourage, and sometimes disgust most of the young people. They are said to be disgusting, difficult and boring, unbearable."
It's obvious that the traditional school, which offers severe curricula and only teachers the repository of knowledge transmission, is not able to form open minded European citizens, able to give their own contribution to the society in our immediate future. The following proposal of teaching innovation, based on webquest and a daily use of concept maps in classroom, makes the pupil indipendent, the master and protagonist of his/ her learning and supports motivations.

1 Introduction

The experience that is going to be explained is the result of a research made by a group of teachers who share a project of teaching innovation in the experimental science field, called "The Words of Science". In such a project particular curricula are experimented, from the Infant School to the Secondary School, by teachers who share teaching strategies based on the problem solving method, cooperative learning, the use of concept maps and laboratory teaching.

The will of changing and the desire of innovation come from the necessity of "motivating" our students, who seem to have lost their interest in Science. The web search and the concept mapping are teaching strategies which can motivate our pupils and give them the opportunity to learn, understand and reorganize the information received in class and in their everyday life. The final purpose is to make them more and more independent in facing new situations.
A webquest on "Water, common wealth of mankind" was done in the first year of a Secondary School, where the students are 12 years old. The choice to build a webquest just on water had different reasons:

- It's a topic in which everybody has a direct experience, so it is possible to build new learning, starting from what students have already learned in the primary school;
- It allows then refresh the concepts, explained trough the particle model of substance, about the water cycle transformations;
- It permits us make problems from different points of view: from the closest (one's territory) to the far off (other realities), from the individual (myself) to the social (the others);
- It stimulates the individual and group awareness through the acquisition of the "limited resource" concept and of the necessity to educate in responsible consumption..

The class takes part in a project promoted by the Museum System Association of the Province of Ancona, with the aim to strengthen the link between school-museum. It considers the conception of a teaching lab in the Museum of Natural Science "Paolucci" in Offagna, elaborated by a class for a class of younger pupils. The following webquest has been thought as an answer to this proposal.

2 WebQuest and concept mapping to encourage metacognition

The webquest created by Bernie Dodge, from San Diego State University, is a constructivist environment of learning, based on the extensive use of the Net and other off-line resources, which can promote the pupils' autonomy in the whole learning process through cooperative learning and problem solving strategies.

2.1 A WebQuest's qualifying aspects:

- Collective learning in which there are experimented all the relational abilities: negotiation, cooperation and motivation.

- Meaningfulness of teaching/learning ties, which are linked to the context of a precise experience. It permits us to find some of the characteristics of informal learning in formal school learning. The students are invited to solve real problems.
- The construction of concept maps, at the end of the learning course, which reinforces the metacognitive aspects related to the realization of the webquest.
- The valuation is authentic, because it is based on self assessment processes.

2.2 The method

The steps for the building of a good webquest are:

1. *Brief introduction* (starting from a question or a problem to solve).
2. *Task* to assign to working groups.
3. *Method* (a card to fill in and 3-4 Net sites to surf, which are chosen by the students and teacher).
4. *Evaluation* (with inter-group exchange, negotiation and self-assessment of the cards).
5. *Conclusion* (communication of the results, also with a concept map). it is the time of metacognition, during which the students analize the strong points and limits of their own knowledge and strategies, and build concept maps. They are stimulated to test the same experience in other contexts.

2.3 The metacognitive aspects develop creating webquest and concept maps

Concept mapping helps students to discover key-concepts and to organize them. First, the pupils formulate individual concept maps, then they share them with the other group mates. In the end, they negotiate the group concept maps. We can see how important and meaningful this phase is, because the students must compare and negotiate a new map, which takes into account the knowledge and the cognitive styles of the group. The verbal communication has a fundamental role. The language gets refined, the pupils build up well structured specific languages, which take roots in meaningful learning processes. The students themselves became aware of what they have learned and how. Sharing their ideas, they understand the value of diversity, and become aware of the points of strength and of the limits of their knowledge and learning strategies.

Concept mapping enhances the metacognitive aspects connected with the webquest creation.

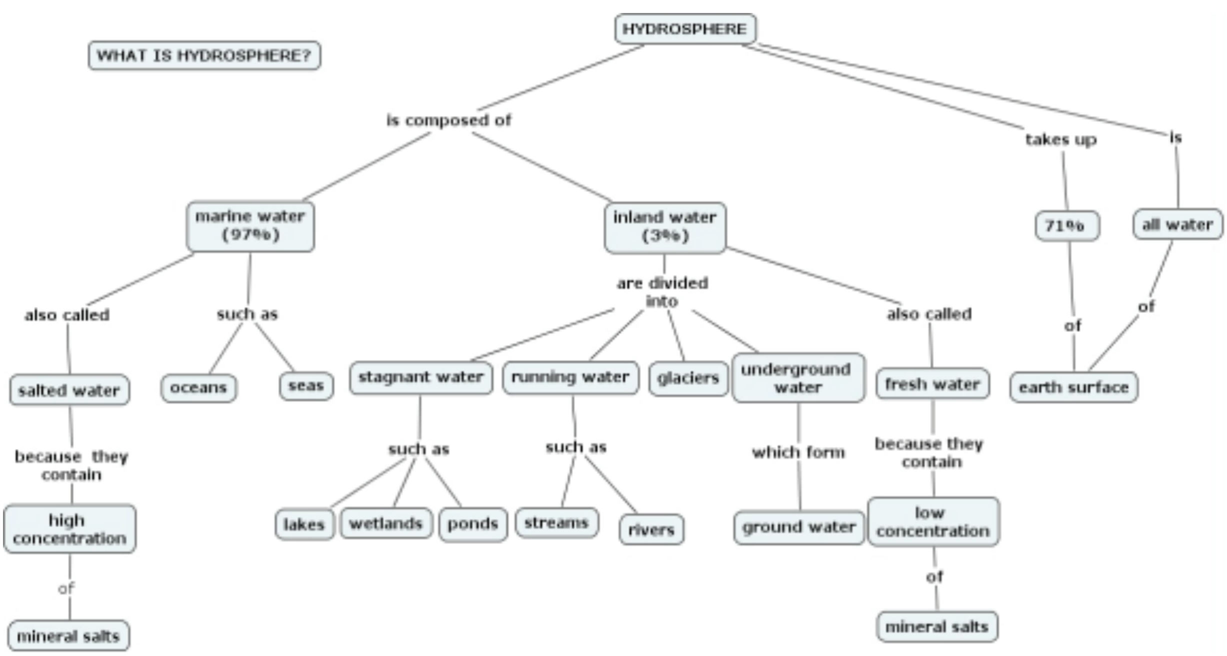


Figure 1. Concept map about the distribution of water on planet earth made in group

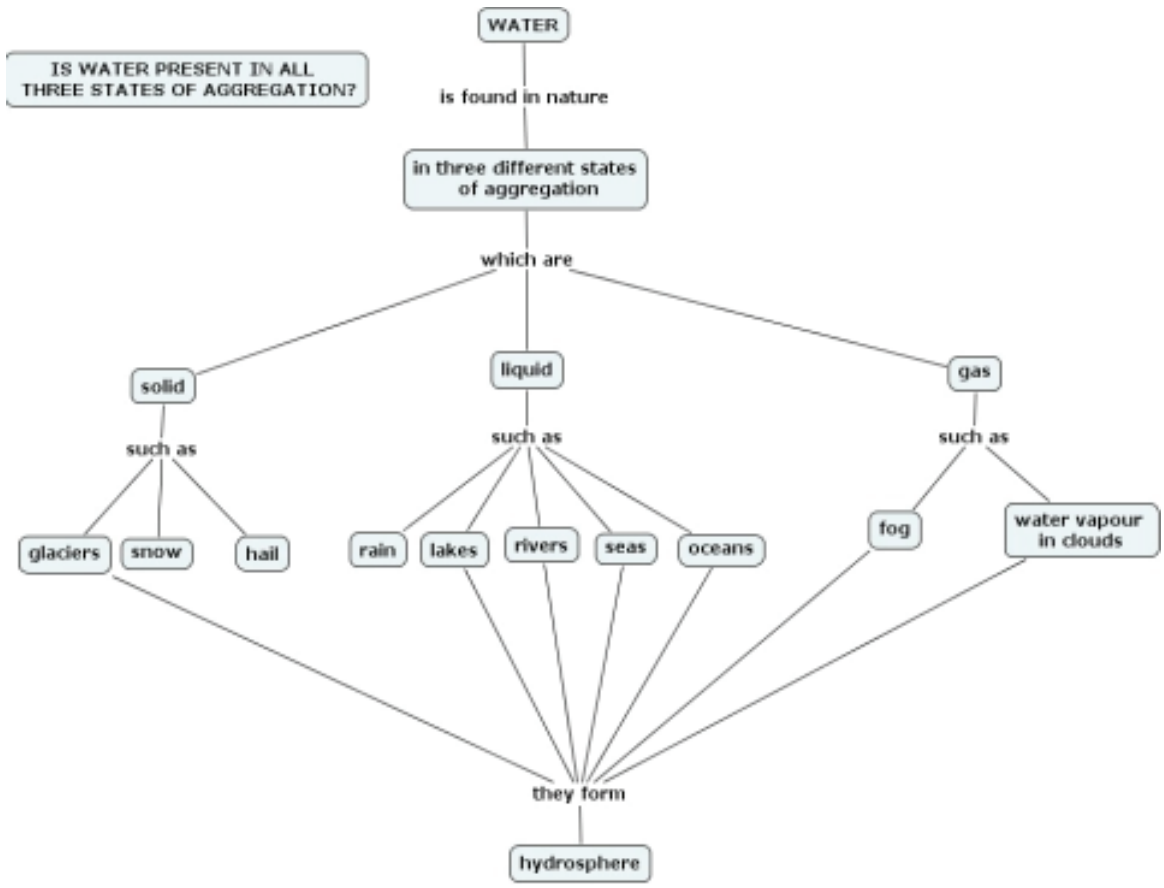


Figure 2. Concept map about the states of water aggregation made in group

2.4 An example of webquest : "Water, the common richness of Humanity"

2.4.1 Introduction

The presence of water in its different aggregation states makes the Planet Earth unique in the Solar System. Such uniqueness is to be found in the physical and chemical properties of this precious compound; so it will be appropriate to examine knowledge through a series of investigations. Water is a vital resource to be protected and defended. Taking care of water is a duty and a responsibility: water emergency is a theme of global interest and every action which involves water consumption must be studied with the aim of saving it.

2.4.2 The task

The Natural Science Museum "Paolucci" in Offagna wants the class (12 year old students) to project a teaching lab about water, which is to be developed by the children of the fourth year of elementary school (9 year old students).

The classmates are divided into six groups, each of them will do the following task:

1. to prepare the introduction to explain the distribution of the water resource on the Planet;
2. to prepare a brief report about water in the different states of aggregation, drawing pictures of the various passages of each state;
3. to plan the experiments which permit the reproduction of what happens in nature in the lab; all the experiments are to be repeated in class and video recorded;
4. to prepare simple experiments about the other properties of water, such as diffusion, capillarity, superficial tension and solubility;
5. to write a story beginning with "If I were a water molecule…";

6. to analyze the different behaviours towards the use of drinkable water, and project the most suitable way to communicate the responsible use of water to children.

Every group will have to build up individual and group concept maps at the end of the investigation to consolidate the metacognitive aspects of the same investigation.

2.4.3 The resources

A list of three, maximum four, websites is given to each group, with the indication of what to look for and where to look.

2.4.4 The course-process

Cards with the indication about the experiments to do and with guide questions are given to the groups to elaborate the results of the experiments The students are invited to build up individual and group concept maps, which aim at organizing and relating the different concepts.

2.4.5 The evaluation

All groups are given:

- An questionnaire of self evaluation of each pupil and of the group;
- An index book for the assessment, where the abilities to check are described by the following indicators:
  1. organization and group work;
  2. participation and involvement;
  3. research of information;
  4. elaboration and drawing up of the final report.

  To each criteria are given 4 levels with a score from 1 to 4, with its corresponding evaluation grid.

2.4.6 The conclusion

Each group fully describes the ways of presentations of the investigations about water to the younger pupils (ages 5 to 9).

Figure 3. The class is divided into groups. These girls are experimenting the phenomenon of capillarity.

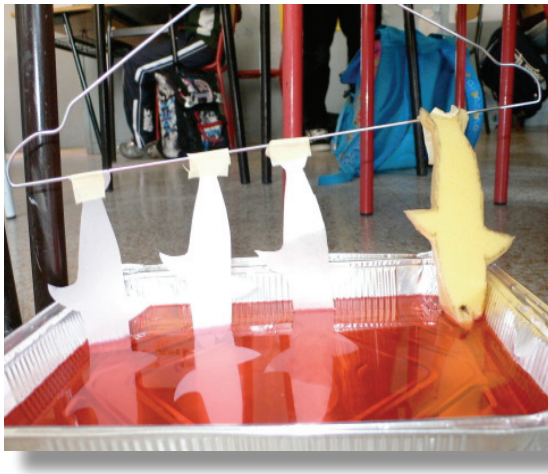


Figure 4. Each fish is made of different stuff. In this experiment it is possible to observe how different materials behave differently in water.

2.5 The scientific laboratory

The experimental activity, above all if led in cooperative groups, can have a very important role for the students, because it allows the learning of knowledge and abilities, at the same time it teaches them to be protagonists. In the Science lab, the students must be able to move and use resources of the lab freely and responsibly, after having made an educative pact with the teacher. The pupils are given complete autonomy and responsibility during the development of the experimental activities so that they can have the opportunity to develop other metacognitive abilities: to interpret the data and to communicate the experiments' results in a correct language.

Figure 5. The pupils are checking the solubility of some substances in water, the concept of homogeneous mixture (solution) and of heterogeneous mixture is introduced.

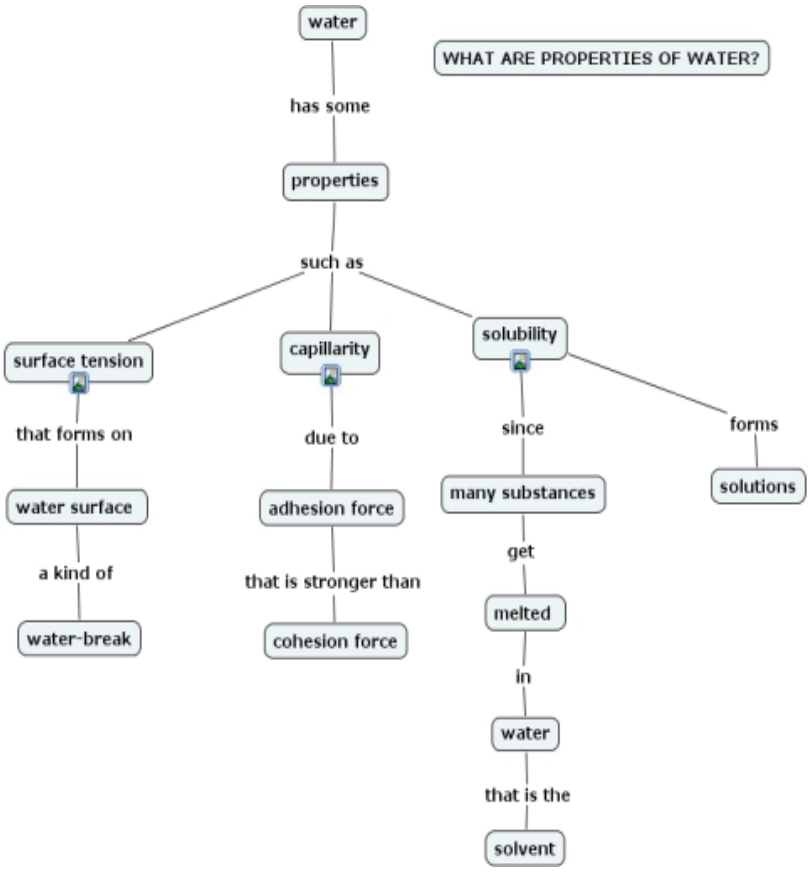


Figure 6. During the lab phase, the students conduct the experiments and elaborate maps to conceptualize what was learned during the experimental and manipulative phase. The maps are individual and from comparison and mutual listening, the pupils build up matacognitive thoughts and the group maps.

2.6 The teacher's role

The teacher has the role of an adviser and assistant of the cognitive process, to make the pupil a real protagonist of his/her own learning. The teacher, watching the students' behaviours, during the planning and experimental resolution of the problem can better estimate the mastery of individual abilities. At the end of the work the teacher:

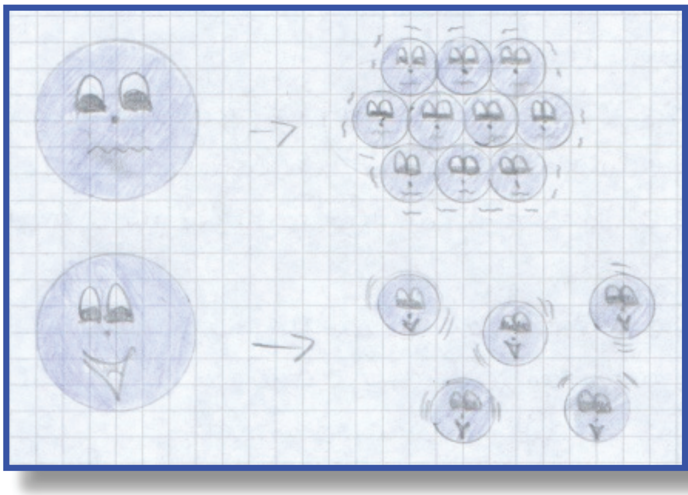
- elaborates the questionnaires;
- assesses each group according to the index book of evaluation;
- stimulates his/ her pupils to think about the work carried out, the acquired knowledge and the way which they have really collaborated.

2.7 "If I were a water molecule…." An example of authentic composition

The students are asked to identify themselves with a water molecule and to describe one of the passages of state or one of the water characteristics, as a story, a tale, or a comic strip.

The stories, the tales, and the strips are socialized with the rest of the classmates that give their opinion both about the originality of the story and about the scientific rigour through which the author was able to tell it. In this phase the mistakes emerge, on which the class will discuss. In picture number 7 we can see the ice fusion, which was reported like this: "I'm a molecule and I've got many sisters. They are very cold, so, to be warmer, they stay very close to each other. Suddenly, I and my little sisters felt a little warm, so we started to move away and, being free, we started to slide on one another." That performance is an example of how formal and informal understanding can interact. To build their stories, pupils used both their imagination and their scientific knowledge.

Figure 7. The students of a group have talked about the fusion of the ice from the molecular point of view and represented it in this picture. In picture 6 there is the concept map of fusion. An example of formal and informal learning interaction.



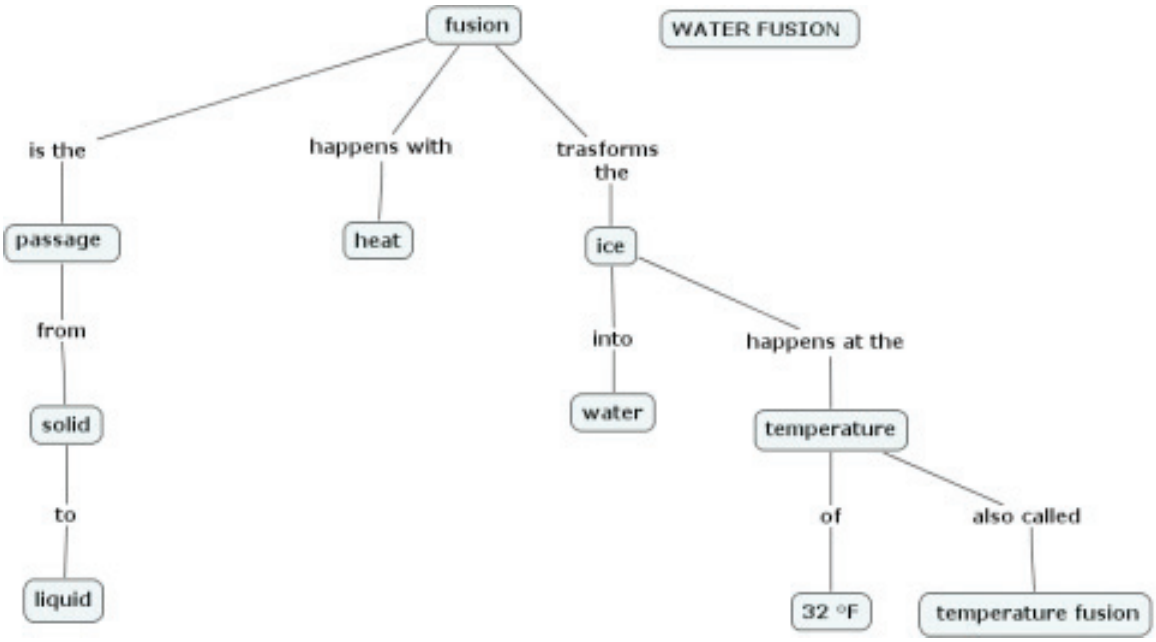


Figure 8. The concept map of fusion.

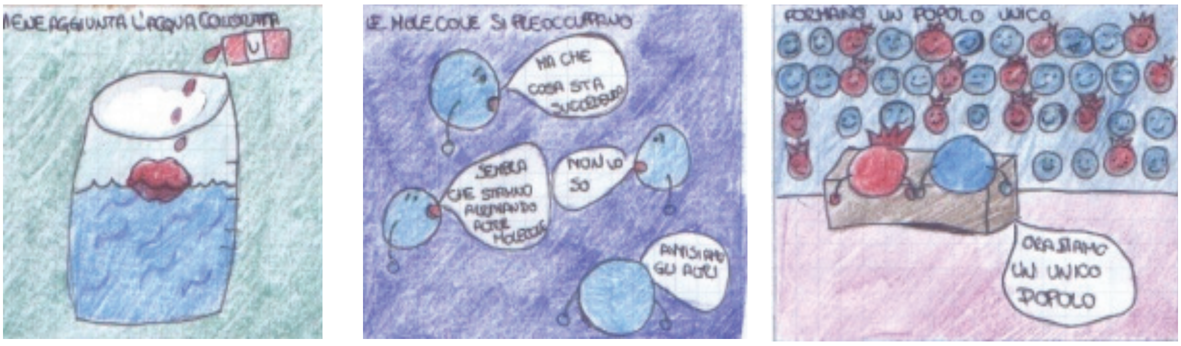


Figure 9. The diffusion of a liquid in water is explained and drawn with the comic strip technique. The story tells of the first difficulty of the molecules of the red liquid to mix with the water molecules which resist. At the end of various fights and reconciliations the molecules of the two liquids mix (diffusion process), being able to mediate a conflict situation, living in peace! In this case pupils have transferred in the scientific area what they have learned in an educational lab to peace and living together..

2.8 Authentic evaluation

Carrying out a webquest means suggesting a significant learning, because it implies the execution of a true task. During the process the student uses all his abilities in coordination. The obtained evaluation is authentic, because it is also based on the contribution of the pupils' self assessment. Evaluation acquires significance as it encourages the pupil to self-knowledge and ~~to~~ motivation.

2.8.1. Analysis of evaluation of the webquest on "Water, the common richness of humanity"

Individual self-assessment

At the end of the assessment process, the following data were gathered:

- 85% of pupils preferred doing activities in group, 15% in pairs: they did not like to work individually;
- at the end of activity all the students were satisfied; 65% were greatly satisfied;
- the more easily respected social abilities were collaboration, listening and taking a decision together;
- the most difficult social abilities to be respected were speaking one at a time and controlling voice volume

Group self-assessment

- most of the pupils found the task interesting but demanding;
- the pupils judged the available materials good and the time sufficient;
- not every body respected the social abilities ;
- taking decisions and collaboration were the easiest social abilities to respect;
- respecting friends' opinions, speaking in turns and controlling the voice volume were the most difficult abilities to respect

2.8.2 Assessment through an evaluation index book

Excellent: [(16-14)/16 points] the group were able to organize according to operative criteria and activated effective strategies in the research of materials. The work is complete and correct and well presented in each part. The pupils respected all social abilities and roles.
Good: [(13-11)/16 points] the group were not able to organize all the phases of the work effectively and not all the pupils showed the same level of involvement, even if, on the whole, they were motivated. The work is not completely finished and corrected but it is well presented. Almost all the social abilities and roles were respected.
Fair: [(10-8)/16 points] the group needed the teacher's help to organize some steps of the work. The division in tasks caused conflicts. They acquired information about some points. The involvement and participation were very little. Half of the work was done correctly. They were respectful of two social abilities at least.
Fail: [score under 8/16] the group could not organize, the conflicts were not settled. They did not obtain any information, as they could not do an adequate research. The group could not become active for the final result. One social ability was respected.

3 Summary

The webquest and the concept mapping have all the necessary characteristics for our pupils' formative success. The most pertinent elements are as follows:

1. they work in a cooperative learning environment and teach students to be respectful of the social abilities, to the comparison, the dialogue and listening, as it is necessary in a more and more open minded and multicultural society;
2. students are motivated because they are asked to put in practice their creative abilities, the abilities of critical and metacognitive thought, and to solve real problems;
3. the pupil is made aware of what he/she knows and needs to learn other concepts and, above all, why and how he/she learns;
4. the pupil learns to self behave in the learning process, to learn for the need and the interest of knowledge, not as a burden.

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CMAP CONSTRUCTION: CHALLENGES FOR THE FIRST TIME USERS AND PERCEPTIONS OF CMAP'S VALUE, A QUALITATIVE STUDY

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Abstract. Constructing a Concept Map (CMap) is not an easy and straight forward process even for a seasoned CMapper. In order to get a better understanding of the specific challenges that CMap creators experience we collected subjective reports of difficulties that novice CMappers experienced during construction of their first map and what they perceived to be the advantages of this form of representation. Comment analysis revealed that the major sources of difficulty for the novice map creators were associated with creating concepts and relationships, planning and organizing the information, keeping their maps focused and avoid including irrelevant information. The design of the study and participants' comments are discussed in detail. This information may be particularly useful to the CMap instructors who train novices.

1 Introduction

Concept Maps (CMap, Novak, 1998) have gained a widespread popularity in educational and knowledge management settings, and it is safe to imply that more and more individuals learn to use this tool. There is a considerable body of research on the application of CMap to improve learning new material (Daley, 2004; Markow & Lonning, 1998; Edmondson, 1995), as a knowledge elicitation methodology (e.g. Coffey et al., 2004; Zanting, Verloop, & Vermunt, 2003; Hoffman et al. 2002; Anderson et al. 2000), and for evaluating knowledge of learner (e.g. Ali & Ismail, 2004, Kinchin, 2000; Roberts, 1999; Williams, 1998). Some authors have reported CMap users' attitude towards this tool (e.g. Markow & Lonning, 1998), or commonly experienced difficulties (e.g. Novak & Cañas, 2008; Cañas & Novak, 2006), however the investigation of attitudes and subjective experiences was not a primary goal of these studies.

In this paper we turn our attention to novice CMappers and examine their experience with constructing a map, namely what difficulties they experience constructing their first map and their subsequent attitude toward this form of knowledge representation. In our study we asked our participants to first build their own CMap on a well studied and familiar topic, and then elaborate on the difficulties they experienced and perceived advantages of CMap form of representation. Since the questions posed to the participants were open-ended, all the reported difficulties and attitudes towards CMap were identified by the participants rather than suggested by the researchers.

A related question to the variety of difficulties that map creators experience is the question of how these difficulties might be mitigated. As a result, another interest we pursued with this study was to investigate whether starting CMap construction with a quantified root concept reduces CMap construction difficulty, at least partially. Quantification significantly reduces ambiguity in the root concept by selecting a dimension within the concept and setting it in motion (Safayeni et al. 2005). As a result, quantification of the root concept narrows down possible set of concepts and linking phrases that could be connected to it. It is then reasonable to expect that building a map starting with a quantified root concept should reduce difficulty with selection of concepts and relationships.

This paper reports on the initial systematic investigation of user experiences and attitudes towards CMap.

2 Method

We conducted a qualitative study through a structured open-ended questionnaire that followed a CMap construction task.

2.1 Participants

150 undergraduate university students participated in this study. All participants were enrolled in a 3rd year Organizational Design and Technology course and received partial course credit for their involvement in the study. The participants were 2nd and 3rd-year students from the faculties of Engineering (83%) and Arts and Sciences (17%). Majority of the participants (88%) had never used CMaps before the study, and 12% of the participant indicated that they had used or seen CMaps in some capacity before.

2.2 Procedure

The study was conducted in a classroom setting. Each participant received a 7-page booklet with instructions. The study was organized in the following way: first, the participants were asked to carefully read all the instructions at least twice, then construct a CMap answering provided focus question, and finally, answer two open-ended questions about their experience with the map construction activity.

2.2.1 Map construction

The instructions in the booklet contained a description of CMap and its elements, example of CMap taken from Cañas and Novak (2006), and step-wise instructions on how to construct a map. CMap was defined as a graph representing knowledge. Definition and description of concepts, relationships, propositions, and overall organization of CMaps with examples were included in the instructions. The focus question and root concept were provided to the participants. All participants constructed their maps answering the same focus question to allow for future content and structure analysis of the maps. The goal of the task was to construct a map that provides a comprehensive answer to the given focus question using no more than 10 additional concepts.

The topic chosen for the CMap task was Ashby's Law of Requisite Variety, which was extensively covered throughout the course. The vast majority of the students in the course had a good grasp of this material – an average mark for a quiz on this topic written not long before the study was 94%. The focus question for the map construction task was "How does change in external variety affect an organization?" The root concept was non-quantified ("External variety") for one half of the participants (N_{NQ} = 76), and it was quantified ("As external variety increases") for the other half of the participants (N_Q = 74). The study booklet contained two pages for map construction – one for practice and one for the final copy – that were blank except for the root concept and the focus question.

2.2.2 Post CMap construction questionnaire

The last page of the booklet contained two open-ended questions, which were to be completed at the end of the study, after the CMap was constructed. The two questions were

1. What difficulties did you experience constructing your map? Please elaborate as this information is very important to us.
2. Do you find that a CMap-representation of this information has any advantages over a usual text representation? If yes, in what context? Please explain your answer.

In this paper we only report on the results of our analysis of participants' responses to the above two questions.

2.3 Data analysis

There were 793 lines of text from 150 participants in response to the first question and 753 lines of text from 149 participants in response to the second question. Participants' responses for each of the questions were categorized based on the similarity of their meaning. The unit of analysis was a comment, which constituted a comprehensive idea regarding an experienced difficulty (question 1) or perceived advantage of CMap representation (question 2). Responses were analyzed with QSR N6 (QSR International Pty Ltd, 2002) qualitative data analysis software.

3 Findings

3.1 Difficulties with CMap construction

Our participants provided 418 distinct comments (on average, 2.8 per participant) pertaining to the various difficulties that they experienced during their CMap construction task. We organized these comments into four general themes, namely difficulties associated with:

- *Concepts and relationships*, 38% of all the comments
- *Planning and organizing* information in a CMap form, 31%,
- Maintaining the *focus* and defining the *scope* of their CMap, 16%, and
- Specific constraints of *experimental task design*, 15%.

Each of the above themes combined several categories of comments. Table 1 provides a detailed breakdown of the four general level themes into categories with respective frequencies of comments from the quantified root concept group, non-quantified root concept group, and the overall for each of the categories. The "Theme/Category/Sub-category" column in Table 1 reports the various categories and sub-categories that contributed to each of the themes. The three "Number of comments" sub-columns report the number of comments for each category provided by the participants in each of the groups and the totals. The "% of comments" column report the percent of all the comments (n = 418) in each category. Below we discuss each theme in more detail illustrating categories with examples of comments.

THEME/CATEGORY/SUB-CATEGORY	# of comments			% of comments (n = 418)
	Non-quant. root concept group	Quant. Root concept group	Total	
1. Concepts and relationships	***81***	***78***	***159***	***38%***
1.1 Identifying and selecting meaningful relationships	30	33	63	15%
1.2 Identifying and selecting concepts	27	16	43	10%
1.3 Wording	19	23	42	10%
1.4 Distinguishing between concepts and linking phrases	5	6	11	3%
2. Planning and organizing	***63***	***68***	***131***	***31%***
2.1 "System" organization	*[21]*	*[19]*	*[40]*	*[9%]*
2.1.1 Establishing flow among several concepts	13	10	23	5%
2.1.2 Limiting effect of existing concepts	5	5	10	2%
2.1.3 Representing reciprocal relationships	3	4	7	2%
2.2 Beginning construction and prioritizing information	17	19	36	9%
2.3 Structural issues	*[14]*	*[17]*	*[31]*	*[7%]*
2.3.1 Overcoming top-down organization/choosing structure	6	12	18	4%
2.3.2 Avoid overlapping lines	3	5	8	2%
2.3.3 Spatial organization	5	0	5	1%
2.4 Lack of solid understanding of the topic	11	13	24	6%
3. Focus and scope	***40***	***28***	***68***	***16%***
3.1 Staying focused, avoid including irrelevant information	29	21	50	12%
3.2 CM does not allow to explain	11	7	18	4%
4. Experimental task design	***30***	***30***	***60***	***15%***
4.1 Limit of 10 concepts	14	10	24	6%
4.2 New to CMap	7	12	19	5%
4.3 Given root concept was a constraint	5	6	11	3%
4.4 Attempt to mimic the example	4	2	6	1%
Total:	**214**	**204**	**418**	**100%**

Table 1: General level themes and categories of difficulties with their respective frequency of mentioning during CMap construction

3.1.1 Difference between the quantified and the non-quantified root concept groups

Contrary to our expectations, we did not find any significant differences in the reports of difficulties between the group that started building their map with the quantified root concept and the group that started building their map from the non-quantified root concept.

Some observed differences were in the expected direction, e.g. fewer participants from the quantified root concept group than the non-quantified group reported experiencing difficulty with identifying and selecting concepts (category 1.2, Table 1) and the focus and scope theme (theme 3, Table 1). On the other hand, more participants in the quantified root concept group than in the non-quantified group reported difficulty with overcoming top-down organization and selecting structure for their map (sub-category 2.3.1, Table 1) and dealing with the novelty of CMap form of representation (category 4.2, Table 1).

However, none of the differences in the themes and categories between the two groups reached statistical significance. We combined the data from the two groups for further analysis.

3.1.2 Theme 1: Concepts and relationships

The most frequently mentioned theme of difficulties was *Concepts and relationships* (theme 1, Table 1). This theme combined comments related to difficulty in *identifying and selecting relationships* (category 1.1, Table 1) and *concepts* (category 1.2, Table 1), difficulty with *wording* them (category 1.3, Table 1), and *distinguishing between concepts and linking phrases* (category 1.4, Table 1). Table 2 provides examples of typical comments for each of the categories in the *Concepts and relationships* theme. The "Frequency" column in Table 2 reports the percent of participants ($N = 150$) that reported experiencing each particular category of difficulties.

Not surprisingly, the most frequent category in this theme was *identifying and selecting meaningful relationships* among concepts. It is worth noting that there is a qualitative difference between the comments in the category *wording* and the categories of *identifying and selecting concepts* and *relationships*. In the latter two categories the difficulty is conceptual, i.e. thinking of relevant concepts/relationships in the context of the given topic and selecting the most appropriate ones. In the *wording* category the difficulty is rather related to phrasing already identified and selected concepts/relationships in a concise and understandable manner.

The least frequent category in the first theme was *distinguishing between concepts and linking phrases*. It was reasonable to expect that this difficulty might naturally arise in the quantified root concept condition of the map construction activity, since root quantification introduces verbs as part of the concept, thus blurring the difference between concepts and linking phrases. However, there was no significant difference in the frequency of comments for this category between the conditions. Thus, it seems that this difficulty was not related to the specific root concept.

Category	Frequency	Typical comments
1.1 Identifying and selecting meaningful relationships	42%	(a) "A lot of the nodes are inter-related, so it was difficult to see which nodes should link to which node so that it helps to answer the question" (b) "After finding the important nodes it is hard to understand how they might relate"
1.2 Identifying and selecting concepts	29%	(a) "It was difficult to determine all related concepts." (b) "I had a lot of difficulty with determining what nodes to include in the CMap."
1.3 Wording	28%	(a) "Trying to find the right words to explain a whole concept or relationship between concepts (*was difficult*)." (b) "I found it difficult to appropriately phrase the propositions, which caused me to doubt my answers."
1.4 Distinguishing between concepts and linking phrases	7%	(a) "Experienced some uncertainty as to what ideas should be framed as concepts and what ideas should instead be framed as relationships between concepts." (b) "Hard to distinguish between concepts and relationships"

Table 2: Categories, their frequencies, and examples of comments for the *Concepts and relationships* theme.

The overwhelming difficulty with identifying, selecting, and wording concepts and relationships that significant proportion of our participants identified was not surprising as even experienced CMappers find creating propositions to be the most challenging aspect of building a concept map (Novak & Cañas, 2008; Cañas & Novak, 2006). The aspect of the *Concepts and relationships* theme unique to novices might be associated with *distinguishing between concepts and linking phrases*, although, no doubt, more data is needed to investigate this further.

3.1.3 Theme 2: Planning and organizing

Planning and organizing theme (theme 2, Table 1) was the second most frequently mentioned theme that emerged from our data. This theme combined comments related to difficulty in *"System" organization* (category 2.1, Table 1), *Beginning construction and prioritizing information* (category 2.2, Table 1), *Structural issues* (category 2.3, Table 1), and *Lack of solid understanding of the topic* (category 2.4, Table 1). Table 3 provides examples of typical comments for each of the categories in the *Planning and organizing* theme. The "Frequency" column in Table 3 reports the percent of participants ($N = 150$) that reported experiencing each particular category of difficulties.

The issues that comprised the *"System" organization* category (category 2.1, Tables 1 and 3) were associated with *Establishing flow among several concepts* (sub-category 2.1.1, Table 1), *Limiting effect of existing concepts* (sub-category 2.1.2, Table 1) *Representing reciprocal relationships* (sub-category 2.1.3, Table 1). These issues, although not very frequently identified by our participants, do point to a different source of difficulty in map construction than just creating propositions. The issues raised by our participants point to the necessity that they felt to unite the existing propositions in a map into a coherent "system," rather than having them as more-or-less independent statements.

Category	Frequency	Typical comments
2.1 "System" organization	27%	(a) "It was tricky to connect several relationships together so that they formed a linked network" (b) "(*I found myself to be*) more preoccupied with finding concepts that fit the existing relations in the map than illustrating the true flow between these concepts"
2.2 Beginning construction and prioritizing information	24%	(a) "It was difficult to start creating the CMap, I wasn't sure what ideas would be valid." (b) "In constructing a CMap, it is difficult to prioritize and relate information in a logical manner. For instance, in this exercise, I had difficulty prioritizing the nodes that meaningfully describe the topic."
2.3 Structural issues	21%	(a) "It was difficult to not to think linearly and draw CMap as two distinct top-down paths without any shared nodes." (b) "Another difficult part of constructing a CMap was to choose a structure, it is hard to clearly define a structure that will work best to answer the question"
2.4 Lack of solid understanding of the topic	16%	(a) "(*it was difficult because you*) need to understand everything before starting your CMap. Essentially, there need to be nodes and relationships in your mind about the topic before you can construct CMaps… It can only best be constructed after learning the stuff that you intend to construct."

Table 3: Categories, their frequencies, and examples of comments for the *Planning and organizing* theme.

Another interesting aspect highlighted by some of our participants was the limiting effect of existing concepts in their maps that constrained the search and selection of other concepts to be included. Individuals felt that the necessity to fit the existing nodes and relationships took priority over representing "the true flow" among the significant ideas. As well, perceived inability to represent reciprocal relationships constrained participants' ability to explain the topic.

3.1.4 Theme 3: Focus and scope

Theme *Focus and scope* (theme 3, Table 1) combined comments in two categories *Staying focused, avoid including irrelevant information* (category 3.1, Table 1) and *CM does not allow to explain* (category 3.2, Table 1). Table 4 provides examples of typical comments for both categories in the *Focus and scope* theme, following the format of Tables 2 and 3.

Category	Frequency	Typical comments
3.1 Staying focused, avoid including irrelevant information	33%	(a) "It was easy to wander off-topic, shift focus/emphasis to related concepts rather than staying on the original concept." (b) "(*it was difficult*) staying focused on question and not including irrelevant relationships: I had to erase some concepts and relationships when I got carried away. It was hard not to get caught up in the details"
3.2 CM does not allow to explain	12%	(a) "Using a CMap to answer a question was difficult, since a question may need more in-depth explanation than is possible in a map." (b) "There was no way to explain the relationship, e.g. "[mechanistic structure] -> does not well handle -> [external variety]", but I couldn't explain why."

Table 4: Categories, their frequencies, and examples of comments for the *Focus and Scope* theme.

Although, the frequency of comments that fall under the theme *Focus and scope* was not very high, one category that contributed to this theme, *Staying focused, avoid including irrelevant information* (category 3.1, Table 1) was the second most frequently mentioned category in the whole set, after the *Identifying and selecting meaningful relationships* (category 1.1, Tables 1 and 2). The difficulty with staying focused on the topic seems to be conceptually related to the *limiting effect of existing concepts* issue from the *Planning and organizing* theme, even though our participants did not make this connection explicitly. Tendency to include concepts in the map that best fit with the existing concepts might easily derail the map construction process. In addition, the explicit requirement to answer the specified focus question might have exacerbated the conflict between including irrelevant information and answering the focus question.

3.1.5 Theme 4: Experimental task design

The last theme of comments, *Experimental task design* (theme 4, Table 1), was the least frequent among the four themes and combined all the comments related to the specifics of the experimental task design that contributed to the participants' difficulty in creating their CMap. Such categories as *Limit of 10 concepts* (category 4.1, Table 1), *New to Cmap* (category 4.2, Table 1), *Given root concept was a constraint* (category 4.3, Table 1), and *Attempt to mimic the example* (category 4.4, Table 1) contributed to this theme.

The main difficulty associated with the task design was the constraint on the number of allowed concepts. Overall, 16% of the participants felt that allowing 10 additional concepts was too constraining, while one individual appreciated this constraint as helping him/her to stay focused. In addition, 13% of the participants commented that they experienced some initial difficulty constructing their CMap since they had not done it before the study and needed to learn the concept of CMap itself. Also, 7% of the participants indicated that the given root concept, i.e. "External Variety" or "As external variety increases," was limiting and made map construction more difficult in comparison to choosing their own root concept. Last, 4% of the participants mentioned that they attempted to mimic the example of a CMap provided in the instructions, which made their map construction more difficult.

3.2 Perceived advantages of CMap form of information representation

In response to the question "Do you find that a CMap-representation of this information has any advantages over a usual text representation," 48% of the participants responded affirmatively and provided reasons why they thought it was the case; 8% of the participants did not find any advantages in CMap representation; and 44% articulated both advantages and disadvantages of CMap form of representation.

Our participants provided 305 comments outlining the reasons why they thought CMap had an advantage over the text representation. Table 5 summarizes these comments providing frequency of mentioning and proportion of all the comments.

CMap advantages	**% of participants (*N* = 149)**	**% of comments (*n* = 305)**
Shows relationships	47%	23%
Shows the big picture/summary	38%	18%
Provides visual representation	32%	16%
Easier to understand/faster access to information	26%	12%
Concise/leaves out unnecessary detail	21%	10%
Facilitates creative thinking	13%	6%
Good way to represent cause-effect relationships and chain/cycle of events	10%	5%
Easier to memorize material	9%	5%
Shows the flow/has different routes	9%	4%

Table 5: Perceived advantages of CMap form of information representation.

The three most frequently mentioned advantages of CMaps were showing relationships among concepts and making them explicit (47% of the participants), providing a summary and a big picture of the topic (38%), and providing visual representation (32%). Interesting issues related to facilitating creative thinking, representing cause-effect and cycle of relationships, and facilitating memorization of the material were also identified, providing a wide spectrum of CMap added value over the text representation.

Although we did not explicitly ask our participants to elaborate on the disadvantages or possible shortcomings of CMap form of representation, 52% of the participants volunteered this information in 120 comments. There were more than twice as many comments regarding CMap advantages than shortcomings. Table 6 summarizes these comments and their frequency.

Predominant disadvantage of CMap form of representation was identified as the lack of detail and not providing explanations, which echoed the category of difficulty with CMap construction, *CM does not allow to explain* (category 3.2, Tables 1 and 4) from the theme *Focus and scope*. This shortcoming could be partially due to the design of the task as it was a paper and pencil activity and did not allow utilizing advanced capabilities of software packages that might have mitigated this problem.

CMap disadvantages	% of participants (N = 149)	% of comments (n = 120)
Lacks detail/does not provide an explanation	26%	33%
Becomes too complicated if large	11%	14%
No logical flow of information	9%	11%
Depends on the content and audience	8%	10%
Need to have background knowledge to understand CMap	7%	8%
Not a good way to learn new material	5%	7%
Does not answer the question	5%	7%
Harder to construct and make changes to	5%	7%
Not effective way to represent one's knowledge	3%	4%

Table 6: Perceived disadvantages of CMap form of information representation.

However, other points raised, such as CMap becomes too complicated when it gets large, having no logical flow of information (i.e. no predetermined sequence for reading the CMap), and necessity of background knowledge for comprehension, etc. might not be easily resolved with the use of technology and might serve as a caution for potential CMap application.

4 Conclusion

Although the most frequently mentioned difficulty with CMap construction were associated with creating propositions, our analysis revealed other issues that CMap creators experience. These are the difficulties with planning and organizing a CMap and maintaining focus and scope. Especially worth noting are the difficulties associated with organizing propositions into a coherent system, prioritizing information, and realizing the inadequacy of one's knowledge of the subject revealed by the map construction process.

Some of the difficulties that our participants identified seem to be more persistent than others. For example, creating propositions (i.e. concepts and relationships) have been reported to be the biggest challenge even for experienced concept map users (Novak & Cañas, 2008; Cañas & Novak, 2006). Whereas other difficulties might be specific to novice CMap creators and could eventually diminish with more practice. At this point, our study cannot identify which of the difficulties are precisely novice-specific as we do not have comparable data from the experienced CMap users. This is an interesting direction for further investigation.

The vast majority of the participants (91%) were able to articulate greater value of CMap form of representation over the usual text after only a single encounter with the tool. The most valuable features of CMaps were articulating the relationships, providing a big picture of the topic, its visual form, and allowing for easier understanding of the material. Yet other advantages of CMap not as frequently mentioned but important to note included facilitating creative thinking, representing cause-effect and cycle relationships, and helping to memorize material in the CMap form.

Still 52% of the participants elaborated on possible shortcomings of the use of CMap without an explicit prompting for this information. Some of the issues identified as difficulties or disadvantages, such as CMap's not providing/allowing for explanation, might be significantly mitigated with the use of CMap software, such as CmapTools. CmapTools allows appending additional information to both concepts and linking phrases in the form of text, images, video, etc., thus providing an opportunity to explain. Yet still other issues e.g. lack of logical flow or difficulty with "system" representation might require a different approach to addressing them.

The use of the open-ended questions in our study ensured that all the reported difficulties and attitudes towards CMap were genuinely generated by the participants rather than suggested by the researchers. It is reasonable to assume that the participants reported the most predominant issues they had experienced with the task; however, it does not imply that the lists provided were exhaustive. As a result, it might be premature to dismiss some of the raised issues on the basis of their low frequency of occurrence. Low frequency does not mean that other participants who did not explicitly stated that particular issue did not experience it, and further investigation through a structured closed-ended questionnaire or an in-depth interview method will provide more information on the issue.

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CMAP LINKING PHRASE CONSTRAINT FOR THE STRUCTURAL NARROWING OF CONSTRUCTIVIST SECOND LANGUAGE TASKS

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Abstract. In constructivist second language (L2) learning environments[1], particularly in relatively teacher-remote situations such as those involving Learning Management Systems (LMS), task performance freedom can be an obstacle to the achievement of specific educational objectives. This paper presents an example of task narrowing achieved by Cmap[2] interface related task design.

The relations represented by Cmap links are defined by linking phrases, so in L2 task involving mapping, by constraining the content of the linking phrases it is possible to constrain learner behavior towards more articulate expression, while still retaining a beneficial degree of task performance freedom. Such constraint can push the learner to very specific language structure behaviors, e.g. forced articulation at the argument level of discourse.

This purposeful constraining of task is illustrated by the author's work with the informal technical academic English register (used for example in science magazines and presentation scripts. This paper presents the process of the author's adaptation of Cmaps and CmapTools for L2 learner analysis of technical text and for the subsequent writing of technical text, using Cmaps for the framing of argument analysis. The approach described here provides the technical academic writing (TAW) learner with a graphical, text-reduced mapping that constitutes a view of how the technical academic genres are constructed, and how they function as carriers of meaning. In conclusion, questions are framed for the development and consolidation of this approach.

1 Introduction

The entry level second language writer of technical academic English is performing a number of cognitive activities simultaneously: recalling lexical units, remembering appropriate register, attending to sentence word order, and orchestrating rhetorical structure and readability. Compounded by lack of confidence in decoding the wording of problems, this imposes considerable cognitive load (Chandler & Sweller, 1992). Maps can support and/or confirm the learner's comprehension of task input language, and can motivate problem solving, thus backgrounding language concerns (Dansereau, 2005). Argument maps serve to clarify the line of argument. Knowledge structure maps (following Mohan, 1986) keep learner attention on the information aspect (rather than the rhetorical) of task, even during learner composition.

The following is an outline of the design process used by the author to arrive at a constrained concept mapping tool for learner use in text analysis and composition. The process consists of three main decisions:

1. choice of map type;
2. choice of text genre for writing analysis samples; and
3. choice of the set of text labels for map links.

The aim of this design process is to create tasks and devices that aid the TAW (technical academic writing[3]) learner in perceiving information structures: argument structure, knowledge structure (following Mohan (1986) and Hunter (2002)) and message type (central message, background information).

	Central message	**Background information**
Argument layer	target content	discard
Knowledge structure layer	avoid	discard

Figure 1. Target structure for text analysis by TAW learners.

[1] Constructivist theory prescribes learning environments that afford learners the freedom to make inferences, discoveries and conclusions, and assume that this will lead to optimal learning outcomes (Jonassen et al., 2006).
[2] Cmaps are node-link maps whose link relations are indicated by linking phrases (text labels). Cañas, A. J., & Novak, J.D. (2006)
[3] Technical academic writing (TAW) is defined here as the science and engineering subset of English for Academic Purposes (EAP), which is the study of the learning of academic writing by second language users of the target language (usually English).

2 Instructional design

The objective of the design process reported here is to clarify the layers of text structure for the technical academic writing (TAW) learner. TAW, the writing of technical academic papers by second language writers, is formulaic: the rhetorical schema is prescribed by academic journals and by the research community. It is also formulaic in that although a logical argument underlies the discourse of the paper, the fashion in recent decades is to leave the argument in technical academic writing implicit. In order to lead the TAW learner to successful mastery of the analytical and composition skills, it is necessary to clarify for the learner that technical academic text success is governed by a number of non-grammar issues, primarily:

1. rhetorical moves vs information units,
2. rhetorical distance (cf. register) (Moffett, 1992),
3. degree of abstraction (cf. argument-information-lexical unit) and
4. readability (Gopen & Swan, 1990).

2.1 Design decision 1: map type

A cursory survey of the concept mapping methods now in general use reveals three main types of text mapping which may be used to reduce such cognitive load:

1. association type dyadic,
2. branching type, and
3. textured-link dyadic type.

Association type dyadic maps consist of nodes joined by lines which indicate the existence of some (unspecified) association in the mapper's mind. Such 'mind maps' are used primarily for brainstorming, but they do not lend themselves to articulate representation of structured discourse such as argument, debate or scientific description.

Branching maps are similar to dyadic mind maps in structure and degree of articulation of concept-concept relations, but the tendency to cluster concepts around a central concept gives the impression of symbolizing only lists and classification (attribute groups) and not the broader range including either argumentation moves (e.g. evidence, background, support, antithesis) or knowledge structures (Mohan, 1986) (e.g. classification, comparison, sequence, cause-effect) or both.

Textured-link dyadic maps specify relations between concepts (nodes), and as such represent can represent information structures at two levels of abstraction: argument structure and knowledge structures, as shown in Figure 2.

Structure	Node content	Link type
Argument structure	Independent clauses	Rhetorical (e.g. argument) relations
Knowledge structures	Nouns/noun phrases	Attribute, compare, classify
	Independent clauses	Sequence, cause-effect

Figure 2. Two levels of abstraction represented in node-link maps.

Cmaps are type 3 maps, having textured link dyadic elements. Cañas & Novak (2006) define the rules of operation for Cmaps:

Rectangles (nodes) contain concepts.
Rectangles are joined by labeled lines called propositions.
Propositions are usually uni-directional.
The label in the middle of a proposition is called a linking phrase.

Given CmapTools' (Cañas *et al.* 2004) ease of use, zero cost, sharability in multiple formats and web readiness, the author's design choice was to have the TAW learners analyze text and compose text structure with Cmaps.

2.2 Design decision 2: text genre for analysis samples

The most appropriate choices of text sample sources for learner analysis are published technical research papers and articles from popular science magazines and newspapers. Magazine articles were chosen for the following reasons.

a. As well as information report genre (impersonal, rhetorically distant, highly formulaic) language, they also contain persuasive and motivating language, while technical research papers by convention contain only report genre. It is essential for this task array that the learners confront mixed genre text.
b. The somewhat loose structure of popular science articles, where knowledge structure information is often mixed with argument structure information, is more similar to the structure of L2 TAW learners' assemblages of ideas than to that of research papers.
c. The register of popular science writing shares many lexical and discourse features with that used in the spoken language of technical academic conference presentations.

2.3 Design decision 3: the array of linking phrases

In the guidance of learner analysis of text with Cmaps, the following rules force the learners to separate persuasion from essential content, and to construct dyads whose English equivalents are concise, logical argument utterances. Based on informal, exploratory observation of learner behavior over a one-year period, the following rules appear sufficient.

1. Nodes must not contain rhetorical devices; those reside in the linking phrases.
2. Nodes must contain nouns/noun phrases/knowledge structures.
3. Relations between nodes must be in the task creator's defined list of allowable TAW relations.

To determine the list of TAW-allowable 'relations' for Cmap linking phrases, it is necessary to examine numerous samples of TAW argument. This work is under way now, and the following are tentative observations.

The relations used in Horn's (2001) argument mapping are claims, rebuttals and counterrebuttals; these were found to be inadequate for representing the detailed unilateral arguments commonly found in popular science articles. On the other hand, Mann's (1999) RST relations are extensive, being designed to meet the needs of representation of humanities advocative-adversarial discourse, and are too rich to (a) represent elegantly the controlled argument format of the research paper genre or (b) serve as low cognitive load tools for second language TAW writers.

A trial and error approach was taken: over a period of one year, instructor-learner negotiation of summary completeness and quality yielded the following list of linking phrases necessary for the mapping of the unilateral argument in technical research papers. The resulting array of necessary and allowable linking phrases is shown in Figure 3.

Citation as subject	Results as subject	Claim as subject
claims (that) proposes (that) implies (that) suggests (that) infers (that) observes (that)	reveals (that) demonstrates (that) indicates (that) disproves disproves proves (that) implies (that)	is supported by is contradicted by is in agreement with is in opposition to assumes (that)

Figure 3. Allowable linking phrases for the argument mapping task

2.4 Negotiating map contents

Instructional design deliberations led to the selection of the constructivist approach (Jonassen *et al*. 2006) for map-based TAW instruction. In this constructivist approach, the learners analyze sample texts and reflect collaboratively to arrive at consensus. By presenting various frameworks for analysis, the instructor can direct the learners' analytical process towards a focus on argument relations and register characterizations.

3 Instructional process

The following is an example of the constructivist process in the instruction of doctoral engineering students (second language users of English) using the text, "Traditional pest control worse than useless," from *The Daily Yomiuri*, March 27, 2008 (see Appendix). The text was chosen for the reasons given in section 2.2 of this paper.

3.1 Phase 1: unconstrained associative mapping

The learners were given the text and instructed to make association type concept maps of the content of the text. To force summarization, a limit of 10 nodes was imposed. Performance was strongly uniform in terms of node content. Generally the learners used the patterns (e.g. subject-verb) of discourse found in the text. The learners reported (and demonstrated) difficulties with associational mapping in terms of

1. Orientation: do relative vertical and horizontal position have an agreed meaning?
2. Centrality: only 3 out of 12 subjects used graphical elements to signal the central node.
3. Over-structure: all 12 subjects placed the topic node in the center of the array.

See Figure 4 for an example.

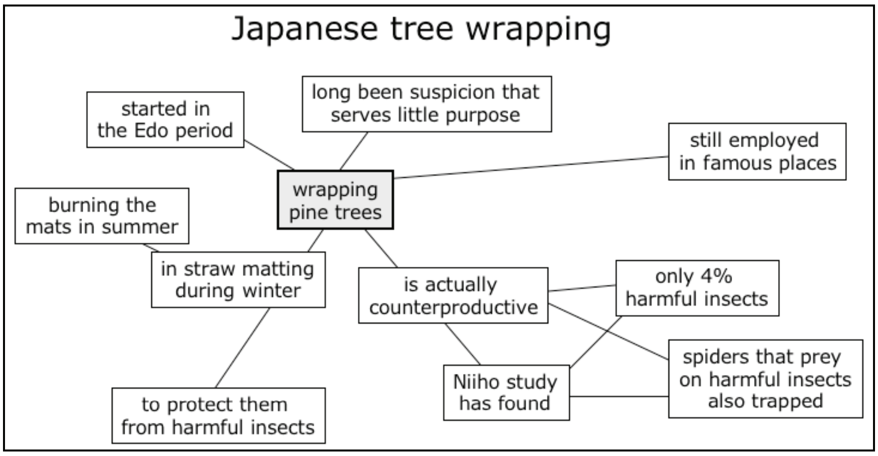

Figure 4. Typical TAW learner association type concept map, constrained to 10 nodes [sic].

3.2 Phase 2: unconstrained Cmap task

The learners were then asked to map the same text again, using CmapTools software, and to "try to represent the argument in the Niiho paper." Figure 5 shows a typical student product. Maps were still highly varied in node content and in link type.

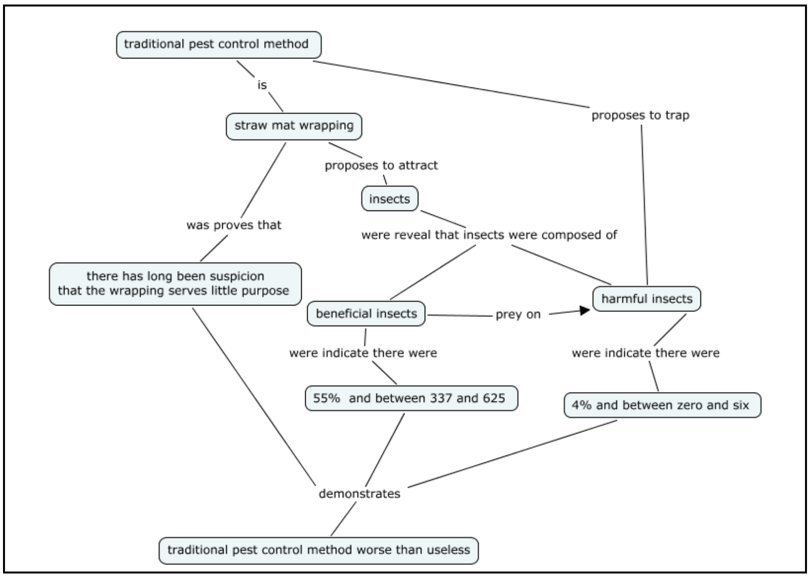

Figure 5. Typical TAW learner lines-of-rhetoric map

3.3 Phase 3: constrained Cmap task

The learners were asked to map the text a third time, again using CmapTools software, but with only the argumentation links listed in section 2.3. Task performance was rather uniform in choice of links from the array above, and map structure and content varied relatively little. The following difficulties were observed in the learners' argument mapping:

1. Some learners ignored the constraint on link content.
2. Some learners added link types (25 occurrences, 5 of 12 subjects)
3. Some learners varied the language in the constrained links (4 of 12 subjects)
4. Some learners added information not contained in the original text (2 occurrences).

See Figure 6 for an example of student mapping in this scenario.

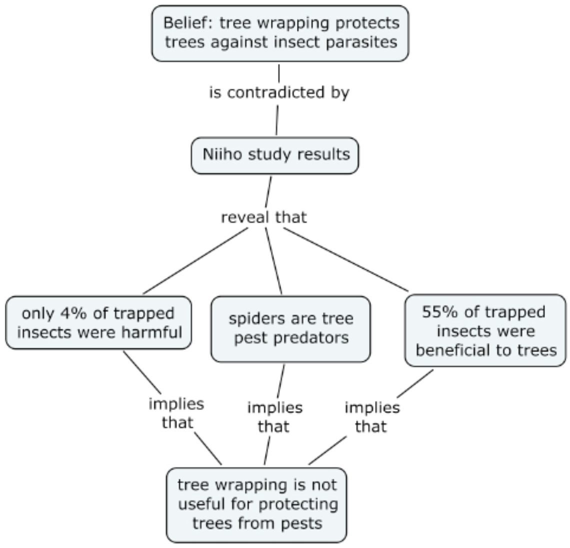

Figure 6. Map with links constrained to argument moves.

4 Conclusion

In the label-constrained mapping approach described here, most subjects did successfully separate persuasive and information-bearing text without specific instructions to do so, and without instruction in how to do so. Of course the mapping approach is not essential to the acquisition of that skill: the value of this mapping approach lies in the visual accessibility of the representation of structured text information, and in the forced low-verbal articulation of relations between argument elements.

Informal observation of learner behavior in constrained-link scenarios suggests that constraining link content can lead TAW learners to accurate, minimal summarization of the arguments in TAW text. The following questions have been identified for future study by the author.

1. Constrained-link maps afford valuable support to TAW learner analysis of text. Do they also afford valuable support to TAW learner composition processes?
2. What is the optimal size and content of the array of linking phrases for the representation of TAW argumentation?
3. Does the *ad hoc* representation technique developed here have implications for a multi-level model of the representation of text-based presentation of information structures?
4. Does the chart in figure 2 present a valid, revealing framework for the classification of argument analysis error?

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Mohan, B.A. (1986) *Language and content*. Addison-Wesley.

The Daily Yomiuri (2008) Traditional pest control worse than useless. March 27, 2008.

Appendix

Text of the article used for analytical tasks.

Traditional pest control worse than useless
The Daily Yomiuri, March 27, 2008.

OSAKA--The traditional method of wrapping pine trees in straw matting during winter to protect them from harmful insects is actually counterproductive, a recent study has found.

Komo-maki, or straw mat wrapping, is a traditional pest control method used to trap harmful insects in the straw wrapped around the trunk. In early winter, straw mats are wrapped around the trunks to attract insects. During winter, the insects multiply in the warm mats, which are then removed from the trees and burned together with the insects inside in early spring.

But a study led by Chikako Niiho, an associate professor of insect ecology at Hyogo University, found that 55 percent of insects caught in straw mats used to wrap pine trees at Himeji Castle in Himeji, Hyogo Prefecture, for four years, were beneficial to trees, while only 4 percent were harmful.

An examination of about 350 straw mats used to wrap pine trees at the castle found between zero and six egger moth caterpillars, a tree pest, each year from 2002-04, and only 44 even in the worst year, 2005. The team found no long-horned beetles--not itself a pest, but a carrier of pinewood nematodes. Together with egger moths, pinewood nematodes are the main cause of pine wilt, a disease fatal to pine trees.

On the other hand, the researchers found between 337 and 625 spiders of various species that prey on harmful insects. Also found in the mats were between 90 and 486 beneficial assassin bugs, which also prey on pests.

According to researchers, egger moth caterpillars live under bark and are found in cracks in the trunk after the removal of mats, with a lot of egger moth pupae found in the same places in summer. Nematodes also inhabit trunks, meaning the straw mat wrapping is useless as a way of getting rid of them.

It is thought that the wrapping of pine trees in winter started in the Edo period (1603-1867), when it was common practice in the gardens of feudal lords. The wrapping has been an annual event at Himeji Castle since the 1960s. But there has long been suspicion that the wrapping serves little purpose.

For this reason, while wrapping is still employed in famous places such as Miho no Matsubara (Miho Pine Grove) in Shizuoka and Okayama Korakuen garden in Okayama, the method was abandoned 20 years ago in the Outer Garden of the Imperial Palace in Tokyo and Kyoto Imperial Palace Garden in Kyoto. Hamamatsu, Shizuoka Prefecture, did not employ the method this year and Hiratsuka, Kanagawa Prefecture, is considering dropping it.

Niiho said straw mats provide places for beneficial insects to pass the winter. Places that want to continue the wrapping should only burn the mats after giving the beneficial insects time to get away, she advised.

A spokesman for Himeji Castle Office said: "It's true we found many spiders in the mats, but as we never knew they were good for the trees we burned them anyway. We want to figure out a better way."

COLLABORTIVE CONCEPT MAPPING IN CONTEXT-ORIENTED CHEMISTRY LEARNING

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Abstract. Teaching chemistry in everyday life contexts has been seen as one way to raise students' interest in science and to educate scientific literate citizens. Teachers, however, often doubt that the actual content knowledge of the field is adequately acquired if it is taught in contexts that might distract the learner. In order to guarantee enough emphasis to be given to the underlying concepts and their relation, this study investigates whether concept mapping as a learning strategy helps students acquire the content knowledge of a chemical topic better than by means of writing a summary. In a one-factorial control-group design, students revise and link the learnt concepts in a collaborative paper-and-pencil concept mapping task. The prior learning environment is highly collaborative in that a problem-solving task relating to a problem taken from the students' everyday experience is presented. Guidance is given by appropriate information material. The two groups are constant concerning their problem-solving task but only differ in the way the content knowledge is revised. According to recent meta-analyses, effects of concept mapping in chemistry are generally small. This has also been confirmed by this study. Positive achievement effects are found in the achievement tests administered directly after the session. However, students in the concept map group do not outperform the control group if achievement is measured in a pre-post comparison. The quality of concept maps and summaries is still to be scored and compared as to the level of performance in relation to achievement test results.

1 Introduction

Since the 1980s, an increasingly significant interest in the instructional effectiveness of concept maps (Novak & Gowin, 1984) can be observed. An expanding interest in how to implement the principles of constructivist learning into classroom practice made it necessary to investigate new teaching and learning methods. This need resulted in research conducted on the various ways of implementing concept maps into classroom practice. As the varieties to use the method as a teaching and learning tool are quite diverse, this is reflected in the research approaches. While cognitive psychologist like Dansereau and colleagues (McCagg & Dansereau, 1991; Hall, Dansereau, & Skaggs, 1992) concentrate on preconstructed maps with a predetermined set of links, other research branches, pioneered by Novak, focus on the cognitive effects of self-generated maps. Other differences in approaching the tool can be found distinguishing computer-based vs. paper-pencil, individual vs. collaborative maps, or maps used as advance organizer as compared to maps recollecting, structuring and expanding knowledge that has previously been acquired. This diversity in approaches shows the need to clarify the implementation method and the research objectives of the concept mapping method as explicitly as possible. The project presented in this paper therefore focuses on self-generated concept maps in the field of chemistry education in early secondary education. The instructional tool is implemented as a collaborative paper-and-pencil task in which students are supposed to recollect and expand the knowledge they have acquired during a preceding small group discussion phase. The method is compared to a control group writing a traditional summary so that time on task is kept constant.

2 Concept mapping as a learning strategy

2.1 Concept mapping in chemistry education

In the field of science education, concept mapping has been introduced to face the problem of linking the often multidimensional nature of the subject. Especially in chemistry students are faced with what has been termed three levels of representation: 1) the macroscopic, 2) the microscopic and 3) the symbolic level (Johnstone, 1993). The underlying chemical concepts can be represented on each level which generally results in students having difficulty transferring the concept from one level to the other (Gabel, 1998). In early chemistry education it is essential to guarantee students' ability to transfer knowledge from the macroscopic level, including concepts from the students' everyday life experiences, to the microscopic level, relating to the underlying concepts of matter like atoms, molecules etc. Students have to acquire the knowledge on the microscopic level in order to explain phenomena on the macroscopic level.

As recent context-based approaches to teaching chemistry like Salters Advanced Chemistry (Burton, Holman, Pilling, & Waddington, 1994) emphasize the necessity to take students' everyday life as a starting point in order to teach chemical concepts, the students' ability of transferring knowledge becomes more and more important. Concept maps can be seen as one means to facilitate this transfer by either linking concepts on the macroscopic level with those on the microscopic level or help students link the underlying concepts on the microscopic level only. This process is always regarded as constructivist in that the learner constructs knowledge by linking the relevant concepts.

With regard to learning in the field of science education, results of two key meta-analyses (Horton et al., 1993; Nesbit & Adesope, 2006) generally show positive effects of concept mapping on students' achievement levels. These effects are, however, highly dependent on the subject domain as well as on other factors such as the degree of involvement and collaboration. Effect sizes vary enormously if domain-specific achievement levels are compared between different fields. While general science education studies have medium effect sizes (d = .52), effects diverge enormously if studies in chemistry education (d = .20) are contrasted to studies in e.g. biology education (d = .67). Other studies conclude that effects also vary depending on further variables such as verbal ability (Stensvold & Wilson, 1990). Furthermore, effects are far too often subject to the applied test instruments and highly dependent on the design. Many studies which did not show any effects stress the fact that an adequate training to accustom the students to the method is inevitable (Markow & Lonning, 1998).

2.2 Individual vs. collaborative concept mapping

Investigating the learning outcome of students in a collaborative setting as compared to individual learning has shown that students benefit from a collaborative learning environment in which they are able to exchange ideas and communicate their knowledge if sufficient guidance is offered (Hogarth, Bennett, Campbell, Lubben, & Robinson, 2005). These findings are reflected in the results of studies which compare individual vs. collaborative concept mapping and its effect on students' achievement. Most studies found higher achievement levels of learners in a collaborative setting if compared to other individual tasks (Okebukola & Jegede, 1988; Czerniak & Haney, 1998). These two studies also show that collaborative CMs score higher than individual CMs. However, research in the field also resulted in studies disconfirming the advantage of collaborative CMs (Van Boxtel, Van der Linden, & Kanselaar, 2000).

3 Method

3.1 Design

The presented study was conducted in an experimental setting. Two groups are compared by means of a one-factorial control-group design. Students worked together on a chemical problem-solving task. This problem-solving task always involved small experiments and was highly context-based in that it related to students' everyday experience. After this phase, students were supposed to revise the learnt concepts either using the concept mapping strategy or writing a traditional summary in order to guarantee time on task.

Treatment group	experimental group (EG)	control group (CG)
Phase 1 (25 minutes)	context-oriented problem-solving task	
Phase 2 (15 minutes)	concept mapping	summary

Fig. 1: Design of the study

The overall unit contained five small group sessions over a week which were carried out after the students' regular school day. The contents of the small group discussions comprised different aspects of acids and bases embedded in different real life applications. The learnt concepts were acquired in a cumulative way as the contents of the previous sessions could always be linked to the actual task. Achievement levels were assessed after each session by a short MC test.

3.2 Sample

Students were recruited from seven secondary schools in North Rhine-Westphalia, Germany. The average age was almost 13 years (M=12.88; SD= .572). Both groups consisted of about 60% girls and 40% boys. In each school, an approximate number of 12 students could be recruited per treatment group so that an overall sample size of N = 147 distributed evenly among the groups and schools could eventually be included in the analyses.

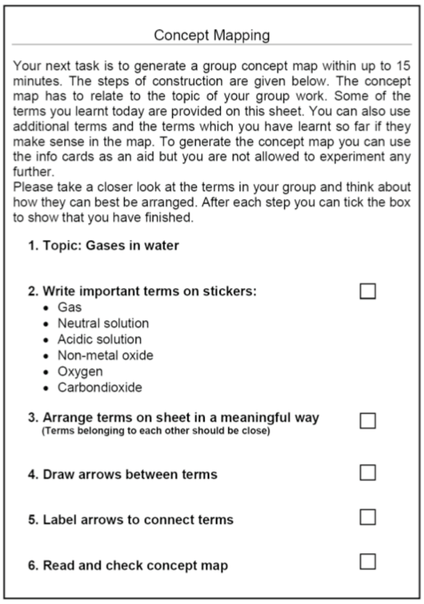
3.3 Instructional Tool

3.3.1 Concept Map Training

As concept mapping is usually not applied in German schools and therefore unknown to students, it had to be introduced and trained. Students in the experimental group were instructed before the first small group session to ensure that they can apply the method and avoid effects because of deficient training. The instruction is based on a student folder containing three different phases of instruction: 1) theoretical introduction of how to construct a CM, 2) a self-generated example CM explicitly following these steps (whole class), 3) self-generated example CM (student task). The example CMs of this training are based on content knowledge which is not part of the study but well-known to the students to avoid cognitive load due to difficult concepts.

The concept mapping method is applied as a paper-and-pencil tool. Concepts are predetermined based on the preceding problem-solving task to facilitate concept map generation as students are neither used to the method nor advanced chemistry learners. The steps of construction are provided on a laminated sheet of paper as an aid (see figure 2).

In order to offer students the possibility to move concepts around, stickers are distributed for concepts. Relations and thus propositions have to be generated by the students themselves and are the focal point of discussion in the small groups during CM generation.


Concept Mapping

Your next task is to generate a group concept map within up to 15 minutes. The steps of construction are given below. The concept map has to relate to the topic of your group work. Some of the terms you learnt today are provided on this sheet. You can also use additional terms and the terms which you have learnt so far if they make sense in the map. To generate the concept map you can use the info cards as an aid but you are not allowed to experiment any further.
Please take a closer look at the terms in your group and think about how they can best be arranged. After each step you can tick the box to show that you have finished.

1. **Topic: Gases in water**
2. **Write important terms on stickers:** ☐
   - Gas
   - Neutral solution
   - Acidic solution
   - Non-metal oxide
   - Oxygen
   - Carbondioxide
3. **Arrange terms on sheet in a meaningful way** ☐
   (Terms belonging to each other should be close)
4. **Draw arrows between terms** ☐
5. **Label arrows to connect terms** ☐
6. **Read and check concept map** ☐

Fig. 2 Construction aid for students

3.3.2 Contents

The content knowledge of one small group discussion phase is limited to five to eight major conceptual terms. The propositions which are to be generated should have been acquired during the preceding small group session. Concepts can, however, also be linked as a result of knowledge acquired in previous sessions so that the concept map may relate to those sessions as well. In this paper, one session is evaluated as an example dealing with the properties of gases dissolved in water (session 4).

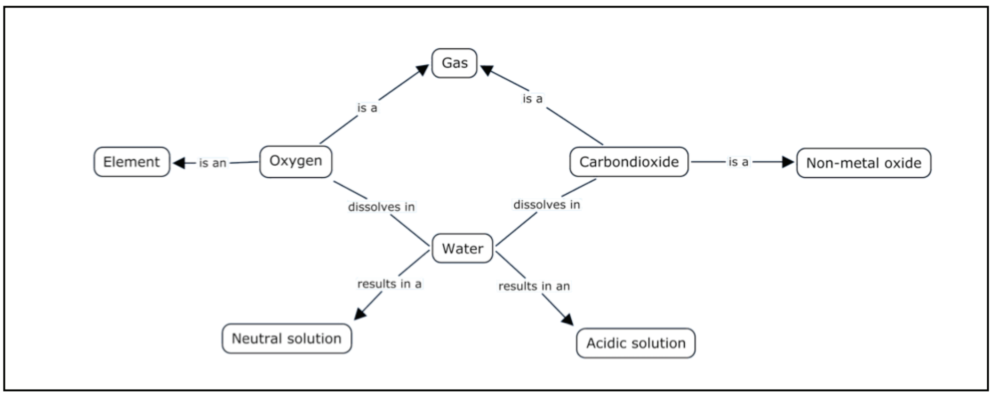


Fig. 3 Example CM of session 4

4 Results and Discussion

4.1.1 Concept Map Evaluation

Concept maps have been scored according to a coding scheme developed by Glemnitz (2007). The quality of propositions and the level of linkage are determined. If the scores are correlated to the achievement test, significant correlations can be found as shown in Table 1 for session 4:

		Achievement test score
CM score	Pearson Correlation	,363(**)
	Sig. (1-tailed)	,010
	N	41
Level of linkage	Correlation Coefficient (Spearman)	,369(**)
	Sig. (1-tailed)	,009
	N	41

Tab. 1 Correlation coefficients of session 4

The correlations are, however, not very high either due to the fact that group CM are correlated with individual test scores or because MC achievement data is not sufficient to reflect the conceptually interrelated knowledge represented by a CM.

4.1.2 Group differences

Students in the experimental group outperformed students in the control condition in the tests after each session ($F(1;147)=4.3$, $p<.05$, $\eta^2=.03$). The effect of the concept mapping task is, however, highly dependent on the particular topic in the session which should be object of further consideration. Generally speaking, the overall effect in the tests administered after sessions is very small. Considering a pre-post-comparison, the achievement effect cannot be found at all.
These results pose questions as which contents can be learnt more efficiently with a concept map than with a traditional summary as well as why achievement effects appear to be very short lasting. In order to determine whether the effects are due to the quality of propositions generated in the respective method, the traditional summaries are scored according to the CMs.

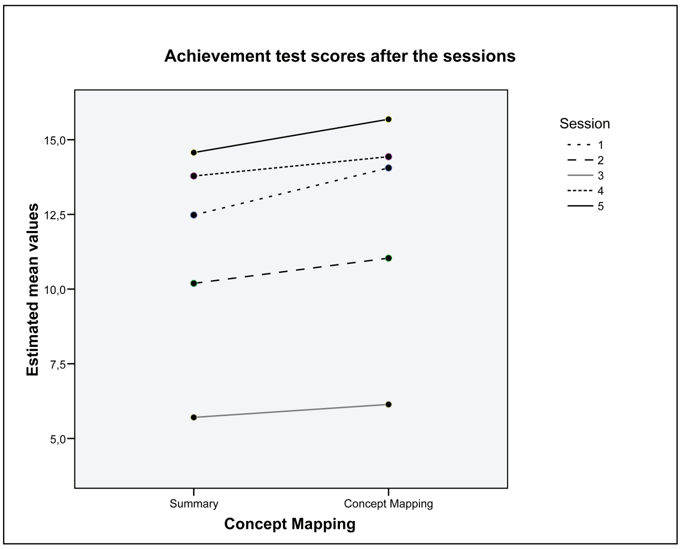


Fig. 4 Group differences in achievement tests after each small group

Analysis of this evaluation is still in progress and cannot be included in this proposal. It can, however, be made available at the CMC2008 meeting as analysis will be finished by this time. The results promise further in-depth results of which factors influence the efficiency of concept mapping as a learning strategy in specific learning contexts.

5 Acknowledgements

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Concept Mapping: Connecting Educators
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COLLABORATIVE CONCEPT MAPPING MODELS

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Abstract. Starting from various examples of practices of Collaborative Concept Mapping within partnerships from different schools countries and students, we will design some models of collaboration, that will be compared and criticized, in the hope that these would be useful to other teachers to challenge and plan suitable strategies to get engaged in similar experiences. To this task it is important to examine first some theoretical background to show the reasons why this kind of collaboration should be recommended as an educative target.

1 Introduction

Our community of practices is aimed at establishing concept-mapping collaboration teams among groups of students from different countries. Differently from other international twinning initiatives (e.g.: eTwining in the European Lifelong Learning Programme) this community is non-official; it is on care exclusively to teachers' free time; and above all it is based on concept mapping only.

The topics of collaborating teams are mainly curricular ones, about environment, citizenship, history, specific science topics, etc., depending on the preferences of the involved teachers. But nevertheless it is possible for partners to deal of intercultural topics or to debate about educative issues among teachers members of the community.

The choice of Collaborative Concept Mapping (CCM in the onwards) has twice the value: concept mapping firstly facilitates the engagement of teachers of non-language subjects, as L1, History, Maths or Science teachers, although a side-support of a L2 teacher is welcome. Secondly, concept mapping is both a communication medium and a target as a learning tool for metacognition.

If these collaborative practices and technologies want to be of positive impact on the local educative communities, they should be agreed with proper objectives and shared expectations from both the school partners, and should be helped with suited strategies to assure an effective interaction and sharing among students. These are the reasons for we want study in depth the educational objectives and the strategies for effective CCM.

2 The context of CCM

Collaborative Learning (CL) is a quite different task in *presence-based* education (for groups of students in the same classroom) and in *distance-based education*, where students may collaborate from different countries. First of all, a *face to face promotive interaction* is not possible anyway in the distance based CL; the mother tongue is often different; communication depends on different technologies and different time zones (for instant messaging); culture, behalf and awareness for cosmopolitanism, educative missions, priorities, objectives, curricula, can differ a lot among the partners. All these differences, that often risk to be undervalued, strongly affect the effectiveness of the collaboration task. Moreover, the relevance of such international collaborations, and the related educative results, are not evenly appreciated and promoted by the different involved institutions. These factors are somewhat related the concept of *governance* introduced by Gowin and Novak (1984). Actually, the entourage that surrounds the collaborating team may modify the development and the *sustainability* of the collaboration, because of presence/absence and quality of feedbacks.

We know by experience that children have a strong affection for mates from different countries and we don't need to make big efforts to convince them that the partners have similar characteristics: they have curiosity, a teacher, an objective, that they are working on shared concept maps etc. We have rather to care sometimes that they can appreciate *differences*, because they identify their partners to themselves. Even if they leave to their teacher the most part of the decisional and strategic tasks, they also rely on their teacher to know that the collaborative task is worthy and this is enough to confirm their strong motivation to carry on the collaborative work and to consider their partners as really being members - friends of the same collaboration team. For the older, the teenager students, we experiment a completely different behaviour. They are generally less curious for every reality not belonging to their life experience and strongly selective about the people and the activities that are acceptable into their *emotive sphere* or that must keep off. It is not enough for them that their teacher believes in the collaboration, because they are highly influenced by the context of other mates, other teachers and parents. If the context is not aware of the meaning of a collaboration, the team becomes informal and not inclusive of the emotive spheres of its members. We should remember that teenagers are more sensitive to the governance factors and that we have to prepare the context, if we want the team working won't proceed as a matter of duties with "strangers" as partners.

2.1 Collaborative learning approximating to cooperative learning objectives

Once governance factors have been considered, the sustainability and the effectiveness of collaborative work depend strongly on efforts towards the attainment of other well known requirements of the Cooperative Learning model (Johnson & Johnson et. al., 1994).

We are aware that *interpersonal and small group social skills* training should be strongly implemented from the very beginning of a collaboration, while *individual and group accountability* need to be assured along the developmental process. Therefore, in the current collaborations experiences, we care for direct – daily communication having place, between student and teacher partners, helping them in the construction of suitable communication skills, technologies and methodologies, independently by the contents to be elaborated in the following CCM activity. This latter would be a sterile one without the vital habit to communicate and leave feedbacks among partners.

Finally, *group processing*, i.e. the reflection on the work of students and their interactions, the focuses on achieving the group's goals and ensuring effective working relationships, has been placed to the teacher's care. But as a matter of principles, this job should be conferred to the team members, in the case of older students.
The objective of Collaborative Concept Mapping via Web is to approach, as much as possible, the five basic criteria of Cooperative Learning, that are: Positive Interdependence, Individual Accountability, Face-to-Face Promotive Interactions, Use of Collaborative Skills, Team Self-Assessment (Johnson et al. 1994). Absolutely speaking, F2F promotive interactions are impossible in distance collaborative learning but a sort of promotive interaction is made potentially possible through the coexistence of feedbacks and contributes, as knowledge claims, coming from different partners of the team. These "ingredients" can generate or not what we call an "*active collaboration process"*: if in a concept map or in a knowledge model there are knowledge claims coming from different members of the learning community that are conflicting, faulty, superfluous, duplicate, incomplete or incomprehensible for someone, we can observe what happens in time. If these faults will provoke some proper feedback, or interactions between the member of a team, we shall affirm that an *active collaboration process* is functioning. Feedback replies are more important than the subsequent editing or adjustments that can have place, also, pushed by the teachers in the unawareness of some members. Feedback-communication is the first warranty that integration between individual views or cognitions is possible. And therefore, this is the condition for the construction of the conscience of being a learning community. So we are continuing with our analogy between the integration process that takes place in progressive differentiation and integrative reconciliation of Ausubel's-Novak's principles and a different integrative process (Novak & Cañas, 2006) that concerns *collective knowledge* (Reigeluth, 1999), both processes being facilitated by concept mapping.

The time lag between the generation of a problem in a dynamic concept map and the generation of a feedback, or the time interval that passes from the feedback and a reply from other members, can be considered as the "clock frequency" that measures the rate of activity of the active collaborating team. An online learning community can have obviously only a reduced rate on respect to face-to-face interacting teams, but we believe that it exists a minimal threshold under which we can declare the process as inactive.

Provided the above conditions are rather complex and not always controllable, the working teams in *our community* cannot be considered as a flat terrain where formal research questions could be easily planned and carried out. They are rather fertile soil where good practices of collaborative concept mapping and amity could be nurtured through the years.

We hope, however, that a greater awareness of the difference between simple *collaboration* and *cooperation* will help us and the future partners, to prepare more effective collaboration teams.

2.2 *Special role of concept mapping*

In the constructivist perspective, a concept map is viewed as a process that reflects the accommodating steps in the changing of organization and definition of individual or group cognition about the same knowledge domain. This kind of concept mapping (Cañas et. Al., 2004, Henao Cálad, 2004) is dynamical in all its aspects and it serves to the learner, to the educator-mediator and to the external reader, in decreasing order of engagement in the dynamical processes-tasks of learning and collaboration.

In details (Novak & Cañas, 2004, 2008) a concept map include concepts, usually inside closed shapes, and relationships indicated by a line and by words on the line connecting two ore more concepts, forming propositions, i.e. meaningful statements o "units of meaning". But a concept map is more than a network of propositions. It has a context that can be identified in a text, a laboratory activity, or a particular problem that one is trying to understand. The awareness of the context and of the domain framework will help to determine the hierarchical structure of the concept map. A good way to define the context for a concept map is to construct a *Focus Question*, that is, a question that clearly specifies the problem or issue the concept map should help to resolve, and that contains the level of arbitrariness of the c-map.

In its dynamic perspective, a concept map can be viewed as well as an open ended platform where a learner structures his attempts of accommodating his/her previous knowledge and to subsume new knowledge. This integrative process has been described as electively facilitated by concept mapping (Novak & Cañas, 2006). In our opinion this is due to *three fundamental and unique properties of concept mapping*, that are:

a) the "immediateness" character, that is the possibility offered by the two-dimensional plane to make coexisting and clearly visible declarations that are separated in time sequence and in the logical flow;

b) the "flexibility" character of concept mapping, i.e. to the possibility of free changing of the concatenations, of the ranks of concepts and to adjusting the type of relations;

c) to the "disciplining" character, consisting in the requirement of make every proposition meaningful, explicit and unambiguous as a statement, or semantic unit inserted with a precise and explicit role in the framework.

We maintain that the same characters of concept mapping work to facilitate integration between cognitions of different people interacting as well, as can be required in the educative mediation and in collaborative concept mapping. Concept mapping becomes both a privileged medium of interaction, comparison and negotiation of beliefs, meanings, opinions about the same subject, and also an educative target as a learning tool that can make a difference in the education of single learners.

An important additional aspect of concept mapping is about multilingual collaboration. As we have illustrated elsewhere (Tifi & Lombardi, 2006), there is a great advantage in sharing ideas and knowledge claims in L2 if these are coded in concept map language, rather that in plain text, for pupils with very basic skills in L2. Due to the elementary propositional structure of concept maps, CCM facilitates the elicitation and the representation of knowledge, reducing the speech to its essentials, simplifying the negotiation and convergence of views for effective communication and sharing, also if collaborators speak different languages. We have proposed the use of bi-trilingual concept maps with bi-tricolour font-typing to facilitate the passage from L1 to L2 and the achievement of reciprocity and mutual understanding of the contents and contexts. Decoding a L2 concept map to L1 is analogously very easier than translating a linear text.

3 Factors for successful CCM

Our first experiments on CCM dealt on the basics: twinning of teachers, creating a community, sharing of tools (IHMC CmapTools) and technological know-how, finding a common model for concept mapping, that is the Novak-Cañas model (Novak & Cañas, 2008; Tifi et al. 2008), adapting it in a set of rules for students facing concept maps for the first time, searching for relevant and interesting topics to develop in the teams, thinking about how to coordinate and alternate the contributes of the students in each team.

We have tried and we are trying different strategies for web-based concept mapping collaborative learning, that are targeted to enhance *positive interdependence* and *motivation* among the members-students. These strategies will be deeply and theoretically discussed and generalized in this paragraph.

3.1 Sources of motivation

Motivation can be as well a good outcome of the process, generated by a happy choice of strategies (above all the preparatory stage), a clever planning setting and initial agreement sharing of objectives.

3.1.1 Starting from curiosity

First of all we should ask why we want to engage ourselves, as teachers, in a concept mapping - web based - collaborative learning project, given that the conditions for learning - in such an unusual modality of education - are sufficiently hard to fulfil even within the boundaries of a single class, locally. We adopt from the children the answer to this question. In several occasions, we have perceived their positive emotive feedback when they were realizing that they were going to collaborate together with other children, "on the other side of the computer", and that those overseas children had the same expectations, the same enthusiasm, same longing to collaborate. So the first rule consists of amplify the emotive impact, by complying their eagerness to exchange personal information with their partners. One or more chat meeting or videoconferences can be a suitable way to achieve this objective, that finds its value also in exploiting the instinctive sense of cosmopolitism of the children.

3.1.2 Choice of the topic

We often choose the topic of collaboration, but a different line of conduct is winning if it should support and guide the children's interest: within a given general theme or subject, dictated by the class curriculum or by the general purposes of the partnership, we should leave the children free to choose the specific areas of interest that they want to develop. Children are often unexpectedly autonomous in defining a field of leading interest, due to previous experiences, or to some information partially known, maybe for the desire to engage themselves in something new with the sake of surprising their partners.

3.1.3 Documentation resources

For the younger, the documents should be properly chosen by the teachers to permit an autonomous and easy research and reading by the children. We have experiences of children that decided autonomously to meet out of school time, to study documents. For older students, it is advisable to let them search for the resources or browse in a predetermined list of links. Moreover, to foster interest and engagement, it is possible to assign a topic that is of pertinence of the other partner (as an example Italian students may study alterations of Nile valley environment, while Egyptian students in the same team could study analogously the alterations of Po river valley, about which Italians are more informed. This exchange of competencies could enhance the reciprocity and encourage the subsequent stage of peer reviewing. Furthermore, another factor that might motivate collaboration is the availability of multilingual sources, as books or as the U.E. portal: http://europa.eu. This is a factor of motivation as it assures that the other partner share exactly the same resources of ours, in the same words.

3.1.4 Quality and timing of interactions

In a collaborational frame, that is for the objective of this paper, it is evident that the collaborating partners working at the same concept map, should decide jointly a knowledge domain and a focus question, and to agree upon criteria and time schedule to alternate and differentiate the contributions of each member and to keep a chronological log of changes.

When the partners have to wait a long time for reading the next contribute of other members of the team, this lead not only to a slow down, but even to a discouragement in that team. This negative factor could be avoided through an agreement of the members of the team to a self-disciplined timetable. For children the respect of scheduled times is entrusted the teachers coordinators.

The quality of collaborative interactions depends on the availability of technological tools as well. A software as IHMC CmapTools includes features that allow students, as well as teachers, to interact and question each other. The easiest way is to use the "Annotation tool", that is a 'post-it note'-type of annotation by which to post short advices or comments on other each others concept maps or on the same shared concept map. When a single knowledge claim has more than one of these alike annotation icons, these become confusing. This drawback can be overcome, with a little more click, by attaching a "Discussion Thread" to any knowledge claim or concept map element (concept node, linking phrase, folder). At a higher level of complexity and potentialities there is another collaboration tool, named "Knowledge Soup". A Knowledge Soup is a repository of shared and independent knowledge claims that are subjected to questioning and negotiation before being picked out and adapted in the concept maps. A knowledge soup can be considered as a preliminary stage that permits knowledge to become meaningful for all team members, facilitating the integration of heterogeneous knowledge in the concept maps, in the next stage. All these powerful collaboration tools, if correctly managed by the students, may stimulate positive interdependence and promote interactions, with efficacy on motivation.

3.1.5 Concept mapping skills

Coding knowledge as propositions in concept map can affect individual motivation towards the collaborative task, depending on the concept mapping skill of every individual member. The syntax of concept mapping can represent sometimes an hard struggle for older students, independently by their metacognitive attitudes and by the meaningfulness of their learning style, because cognitive structure of the adult people can be characterized by high levels of "connectiveness" or by a prevalence of complex sequential structures that aren't easily reducible to elementary propositions, relatively independent one of each other (Tifi et al., 2008). Not everybody accept the worth of deconstructing in depth and recoding their knowledge in such "format" that follows a set of "strange" rules. This is true especially if these adult students haven't ever had experience in concept mapping in their previous education. The same problem is very attenuated for children, as they have naturally a language that is closer to the elemental articulation of concept maps. To prevent a possible "discouragement effect" in the "predisposing" cases, we suggest some precautions: a mini-training session can be proposed, accompanied by a video or a presentation of the several steps in the construction of a concept map, where the application of each criterion is well highlighted, and by an exercise of constructing a concept map from a short and familiar text, followed by a proper feedback from the teacher-trainer. A similar training can be also useful to prepare the team members to use the collaboration tools and other basic features of the software.

The preparation of "skeleton concept maps" (Novak & Cañas, 2004) can also help to overcome the initial impact due to conventions of concept mapping. In these "initiated concept maps" the focus questions have been already stated, the root concept (that is the top high concept in the pyramidal structure of the c-map) and some of the first level concepts, have been already placed in the layout, together with some other nodes that need to be labelled, suggesting a possible structure to be continued.

3.1.6 The products of collaboration

We know, as educators, that a good process is more important than nice final products and that our best result is when the online learning community wants to keep collaborating in the future. Nevertheless students in the learning community need a precise and concrete target to attain. This target could consist in a reviewed concept map or knowledge model made of a certain number of pre-assigned focus questions and concept maps answering to these questions. Sometimes the lack of such a well defined target (because of the "open-endedness" of sources and of all knowledge) is interpreted as a sign of arbitrariness that may be used to "justify" a sort of permission to get rid of the individual responsibility and of the care for interdependent team processing. The background idea is that the possibility of having a clear objective to pursue, that is perceived not too far from the current attainment, can represent a motivating push.

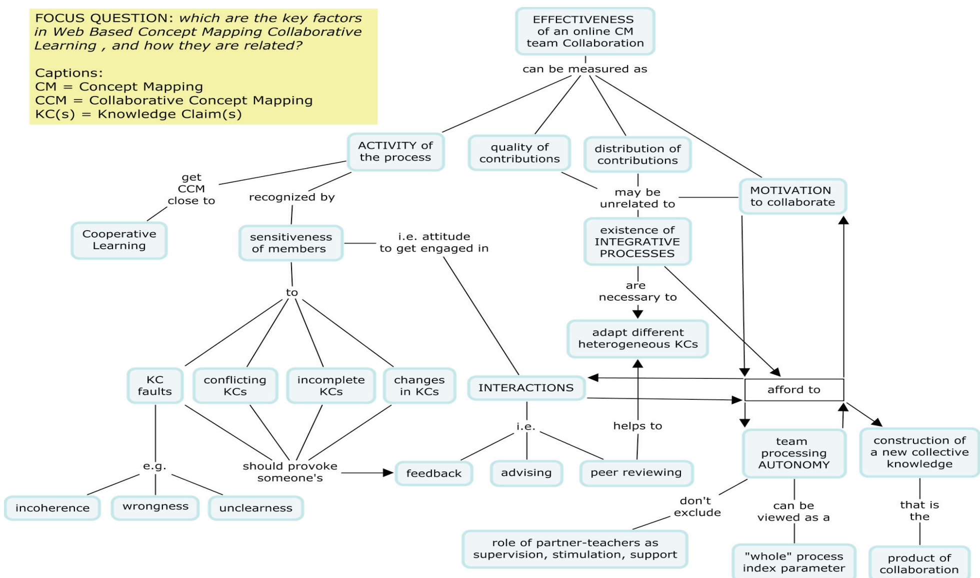

Fig. 1. Key influences in Web based CCM, as elicited in the analysis of motivation related factors. Double arrows indicate a synergy effect.

3.2 *A survey of strategies and methods*

The key aspect of a concept mapping collaborative learning process is represented by the method used to integrate knowledge claims and sharing of productions.

3.2.1 Comparison of independent concept maps

The easiest form of collaboration is when partners work on separated multilingual (for the sake of mutual comparison) concept maps on the same topic (maybe with the same focus question, yet generally biased for local context, environment or culture). Partners are tied up by the sharing of the same task applied to their local realities. Motivation to know the contributes, and to interact with the other partner, comes by children's curiosity and by the teacher's push to make them learn from pears instead of textbooks, and is not demanded by true interdependence. Collaboration among younger children was often set in such way that has its strength points in the simplicity and freedom of timing.

3.2.2 Alternated contributes on shared concept maps

A little more complex type of collaboration uses an alternation of contributes from the several partners on the same shared concept maps, or a mixed strategy of independent development that is followed by addition of contributes and revision –accompanied by restructuring claims - from a different partner.

The first sub-method of "simple alternation" seems more practicable than the mixed one, for younger children, because the mixed one requires an higher level of mastery in the comparison and in the criticism and rearrangement of concept maps and of knowledge claims of each others, in a *non-additive-integrative* process that is more feasible with high school students and adults. Children are more likely concerned in exploring and taking note of the contributes of the other partner and in finding further evidences and knowledge claims to answer the focus question, in a substantially *additive* process. The extent of interdependence is evidently higher in both these forms of collaboration than in the comparative strategy (3.2.1).

3.2.3 Mixed alternated-independent concept mapping and peer reviewing

As we have depicted in 3.2.2, in this model the different partner initiates to construct individual c-maps and then, first to become more complete, these c-maps are examined and reviewed by the partner. The revision consists of putting annotations with claims or suggestions, or of adding new propositions, copying and reorganizing the c-map in a different arrangement. This means that this model of collaboration has as a strength point that is more flexible and less constrained than the one that is based on alternated contributes on c-maps that are shared from the beginning. It has as a weakness as being characterized by scarce interdependence in the first stage of unshared concept mapping.

3.2.4 Shared concepts + peer reviewing

The strategy based on *sharing of concepts* has been used successfully to maximize the interdependence in a CCM collaborative learning team that was created with the purpose of facing a *new curricular topic* (atom) that was previously chosen by the two teacher partners. The two teachers agreed to divide the theme in four sub-themes, described by as many focus questions that formed a continuum in the curriculum. Each subtheme was assigned to a sub-team. The first stage was the *search for the key concepts* in every context, a task that was accomplished collaboratively. Italian (Divini's) and Rumanian (St. O. Josif's) students picked out concepts through the examination of resources in the mother tongue that were selected in advance by the teachers, mainly from the course textbooks belonging to the students, but also from shared resources from the web in English. It is important to notice that *a)* the work of concept eliciting has been continued also in the subsequent work of concept map construction, as students went into the concern; *b)* they were informed of the focus question of each sub-domain of knowledge when they started this job; *c)* contributes-exchanges of relevant concepts from other sub-teams of the same community was welcomed at that stage.

In the second step, the local groups of Italian and Rumanian students in each team copied separately the concepts from the gathering page and pasted them into new empty resource file, where they started to construct new concept maps, being minded of the sub-topic focus question. Remarkably, during this stage the students frequently asked their teachers for supports to understand the hard points of the subject and for suggestions about the organization of knowledge in their maps.

In the latter stage, it was initiated a work of peer reviewing, where the Italian students reviewed the Rumanian concept map in the same subtopic and vice versa, through addition of annotation queries to the partner. The critical innovation in this project has consisted in the use of shared gathering concepts. This task was appreciated for its simplicity to give interdependence and trigger collaboration from the very beginning.

3.2.5 Collaborative reading of texts + Knowledge Soup sharing

The three partners collaboration project “History Maker Molecules”, that we’ll call HHM onwards, constituted an experiment about *collaborative reading of a shared book,* facilitated by concept mapping and Knowledge Soups. The two distant Italian partners and the Spanish one, shared the same book, *Napoleons buttons,17 Molecules that Changed History*. This book had a high motivating and intriguing power on both teachers and students. Six students from 14 to 16 years old from each partner school have chosen three chapters of the book by means of a poll based on the titles and paragraphs index. Two students of each class have been assigned to each chapter-team based on the priority criterion of their previous preferences, and so forming three teams of six students. Working on the English edition of the book for all, team students started to gather relevant knowledge claims from *portions* of the chapter. This task was accomplished by means of highlighting paper copies of the text. Then the students were instructed to transform such elemental knowledge claims in “mini maps” that were copied and shared as “gathering resources” i.e. as c-maps through CmapTools. This step is not as easy as it seems, because this kind of analytic reading implies *a)* to elicit concepts and relations, *b)* to decide which concepts are subordinated to which and *c)* to choose the way to “quantify” the top-concepts, i.e. how to cluster attributes and to create articulated concepts adaptable to the context. The effort in analytic reading was also the main reason that made this project so interesting for all the involved teachers.

From the gathering c-maps, the next step was to collect knowledge claims in a Knowledge Soup, a task that is automatically accomplished by associating the gathering resource-map to a *Knowledge Soup*. The knowledge claims coming from all the gathering resources of the same chapter, have been easily published in the Knowledge Soup of that chapter. Finally, the students begun to assemble the knowledge claims as propositions in several c-maps for each chapter, obliged by the rule to insert at most four propositions a time in the same map, and then waiting the contribute of another partner, before to add further knowledge claims. This rule was established to prevent asymmetrical developments of the shared concept maps by one of the partners, and it was effective to set up interdependence.

This experience was very rich of advices for us, and as a conclusion, the lesson for future experiences in collaborative reading in L2 (perhaps also in L1) can be synthesized as follows:

1. The units of reading, from the book, should be narrowed to single specific contexts, each of them containing no more than 30 - 40 concepts, prior of being faced collaboratively;
2. the analytical reading of each reduced unit should be accompanied by direct concept mapping by every member and direct publication of knowledge claims in a single shared knowledge soup for that unit.
3. the whole team should deal with one of such units a time, progressing from each unit to the next, until the complete chapter would have been read and transformed in customized individual concept maps. Knowledge Soups should be used for sharing claims and interacting with the partners through discussion threads, questioning advices, and propositions in the concept maps.
4. a skeleton c-map could be used to create an hyperlink-index guide to the browsing of the knowledge model about the book, and, at the same time, it can be further developed from top – down to give a deeper vision of the chapter as a whole ensemble.

The complete documentation of all the experiences is available from the Authors by request and navigable from http://www.2wmaps.com/Eng.htm, link “Keyhole”.

4 Conclusion

Our research of optimum strategies for distance CCM is not ended yet, and it is worth to remark that suited solutions can also be freely searched for in each team, depending on the requirements of the topic to be faced. The model for CCM cannot be taken for granted anyway, and the collaborators should agree and be aware of it.

Collaborative Learning via Concept Mapping is in our views an open door towards great opportunities: to enhance education of students, to offer positive stimuli for the governance quality of the institutions, and challenges for the teachers engaged in new methodologies and technologies. We strongly believe that collaboration in an international team group helps to improve a second language, to acquire an intercultural sense, to widen the students’ self-perspective and the interest for the others, to overcome the sense of closure due to the repetition of curricula and to the crystallisation of roles. Beyond the opportunities to make our students protagonists, we wish them to share new communication experiences - collaboration tools and resources through the web. In this sense, differences rise to the role of resources.

Finally, we believe we are reaching our first aim as founders of this community (promoting concept mapping in education), provided we are realizing that some students are creating concept maps for their own studying purposes, from outside of their working team.

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Tallinn, Estonia & Helsinki, Finland 2008

COLABORATIVE CONSTRUCTION OF A CONCEPT MAP ABOUT FLEXIBLE EDUCATION

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Abstract. We are going to describe an experience in which the Concept map is used as a flexible tool in order to construct, organise, navigate, criticise and share knowledge. We have developed it in one subject of the last year of the Pedagogy degree in which from a list of concepts handed in to the students we have created Concept maps elaborated in an individual way and, subsequently we have related them in a collective map.

1 Introduction

The main axis of the experience we present is referred to the application of the Concept maps in the process of teaching-learning, emphasising the representation and the fact of sharing the knowledge from a constructivist perspective (Novak and Gowin, 1988; Novak 1990, 1991; Cañas et al., 2000). All these authors share the idea, widely accepted of the constructive activity of the student in the process of learning and, they consider that the concepts and proposals, which link the concepts, are central elements in the structure of the knowledge and in the construction of the meaning as well.

The construction of the Concept maps correspond to the basic principles in the meaningful learning (González and Novak, 1996), facilitates the capacity to learn to learn by means of the construction of own knowledge in the students, and it comes to be a highly useful tool whenever we have to represent the contents in a global and organised way, giving at the same time the possibility of its distribution through Internet. It consists on using them as cognitive tools in the nomenclature of Jonassen (2000) and, they are fundamentally used in order to widen, promote and reorganise the capacities of the students going beyond the limitations of the human mind.

The usage of the Concept maps is known as didactic resources: the uses that can be done are different and go from the usage of the lecturer as media to represent the information, to the creation of maps by the students as much individually as collaborative way. Therefore, we have tried to tackle the subject matter of the Concept maps from different perspectives: as a tool in hands of the students to organise the information about one concrete theme, as an evaluation tool for the teacher, as organiser in the design of materials for the learning and as a teaching-learning strategy.

Our main interest is based on the potentiality that presents as much the student's representation of the knowledge as share, contrast and organise a map created in a collaborative way. Moreover, the Concept maps are the suitable mechanism to create modules of independent contents (associated in our case to the map of each concept). Each map, by definition, expresses the knowledge about one specific context. A group of related maps can collect the content of one subject. These maps, obviously, will have links to maps with other subjects. However, this relation is not due to the sequence of the course but to the content. Each module of the subject becomes one independent unit and, at the same time integrated in the general subject (Flexible Education). The Concept map is used as a flexible tool to construct, organise, navigate, criticise and compare the knowledge.

2 The experience

This experience has been carried out in the subject 'Design and development of programmes of flexible and distance education' that belongs to a curricular plan of the Pedagogy Degree at the University of the Balearic Islands. It is about a subject that is given in an face-to-face modality although doing some work online through networked materials and tools. They use the knowledge based on the elaboration of Concept maps with respect to the students as a base for the creation of communication and learning atmosphere. We have used the Concept maps (Novak and Gowin, 1988) as strategies for the cognitive organisation. As well as the platform used in the course, it has been also used a software tool which allows the user the collaborative work[1] and others which provide the construction of Concept maps[2], connecting concepts to each other through semantic links and complementing them through images, videos, pictures, graphics, texts, www pages, etc.

[1] The tool work we use for the collaborative work is the BSCW (Basic Support for Collaborative Work).
[2] The tool chosen to design and represent the Concept maps were CmapTools (Developed by the team of the Institute for Human and Machine Cognition), free and versatile tool which can be very well adapted in the usage of this subject.

The students, besides constructing their Concept maps in order to show graphically their knowledge about the corresponding concept, collaborate digitally between them in the construction of their maps. They link them to the maps of the other students, publishing their model in the Internet, allowing the other students surf their web pages, and contributing to organise the knowledge about the subject.

The work, which we refer in our experience, consists on the whole group constructing the Concept map of the concepts related to the subject, which we will call COLLABORATIVE CONSTRUCTION of CONCEPT MAP about THE FLEXIBLE EDUCATION. They should construct the Concept map and associate it to the relevant material. Other students should examine and comment these maps, modifying them or adding new elements, creating alternative versions.

We understand that the Concept maps constitute a suitable mechanism for the creation of each independent module, when we represent the knowledge about each specific concept and when we provide a group of related maps, they can collect the content of the main subject: the flexible education.

In this way, the work on the one hand, constructing an individual map of each one of the main concepts of the subject –which will obviously be related to the kindred concepts – and, on the other hand, organising the map of all these concepts, which include such maps and relevant material of the subject. They will arrive to the last result by consensus through the cooperation between the members of the group. The work, which is based on the strategies of the collaborative work, composes a variety of activities from the students related with their research, selection, organisation, exchange, organisation of the concepts and their relations.

The experience was developed during five weeks (nov-dec, 2007), previously carrying out with the students in an introductory workshop about the creation of Concept maps and the use of the programme CmapTools. In the experience participated 32 students.

As figure 1 illustrates, the work consisted of two stages clearly distinguished:

- The first stage corresponded to the individual work, in which a concept was assigned to each student and should get information, locate the relevant material related with it (articles, web pages, etc), study it, so that he can elaborate his Concept map.

- The second stage corresponded to a tuning in common of all the studied concepts for each student. They should establish relations between the concepts, through a process of "negotiation" between all the members of the group, using different communication media provided the students (own of the platform Moodle and those of software for collaborative work). This stage concluded with the discussion of the map that has been configured, shaping new adjustments and modifications.

2118

COLABORATIVE CONSTRUCTION OF CONCEPT MAP about FLEXIBLE EDUCATION

Individual and collaborative work[1]
Submit date: November 13, 2007

The task consist to build, between the group class, a concept map with concepts related to the subject and it will called **COLABORATIVE CONSTRUCTION OF CONCEPT MAP about FLEXIBLE EDUCATION**. You must build the conceptual map and associate it relevant material. The other students should review and comment on these maps, modifying or adding elements, creating alternative versions.
According to the premises of collaborative learning, the task must be developed in a collective non-competitive context, in which all members of the group contribute to the learning of all, cooperating in the construction of knowledge. The task will be achieved through the direct activity of each member individually group and through the consensus between members of the group.

Procedure:
1. - a concept will be distributed to each student. You must study it and locate relevant material (images, web sites, documents...).
2. - you must seek concepts related to yours and establish negotiation with the other student who is working with that concept or concepts to establish relations among them. For this stage will be used BSCW sharing workspaces (folders) with those colleagues who work related concepts.
3. - you should put in the Collaborative Map (Located in the folder: 2118 in IHMC Public Cmaps 3 Server) each of the concepts with their links and relevant materials (resources).
4. - the map will be checked in each stages and commented, suggesting changes, new elements, etc.... These proposals, comments, etc.... will be carried out in the discussion list associated with the Collaborative Map.

Figure 1. Instructions to carry out the activity.

A concept of this relation of main concepts was assigned to each student and should get information, locate the relevant material related with it (articles, web pages, etc), study it, and elaborate a Concept map about. Each of the individual maps created by the students were put in a common Server (figure 2).

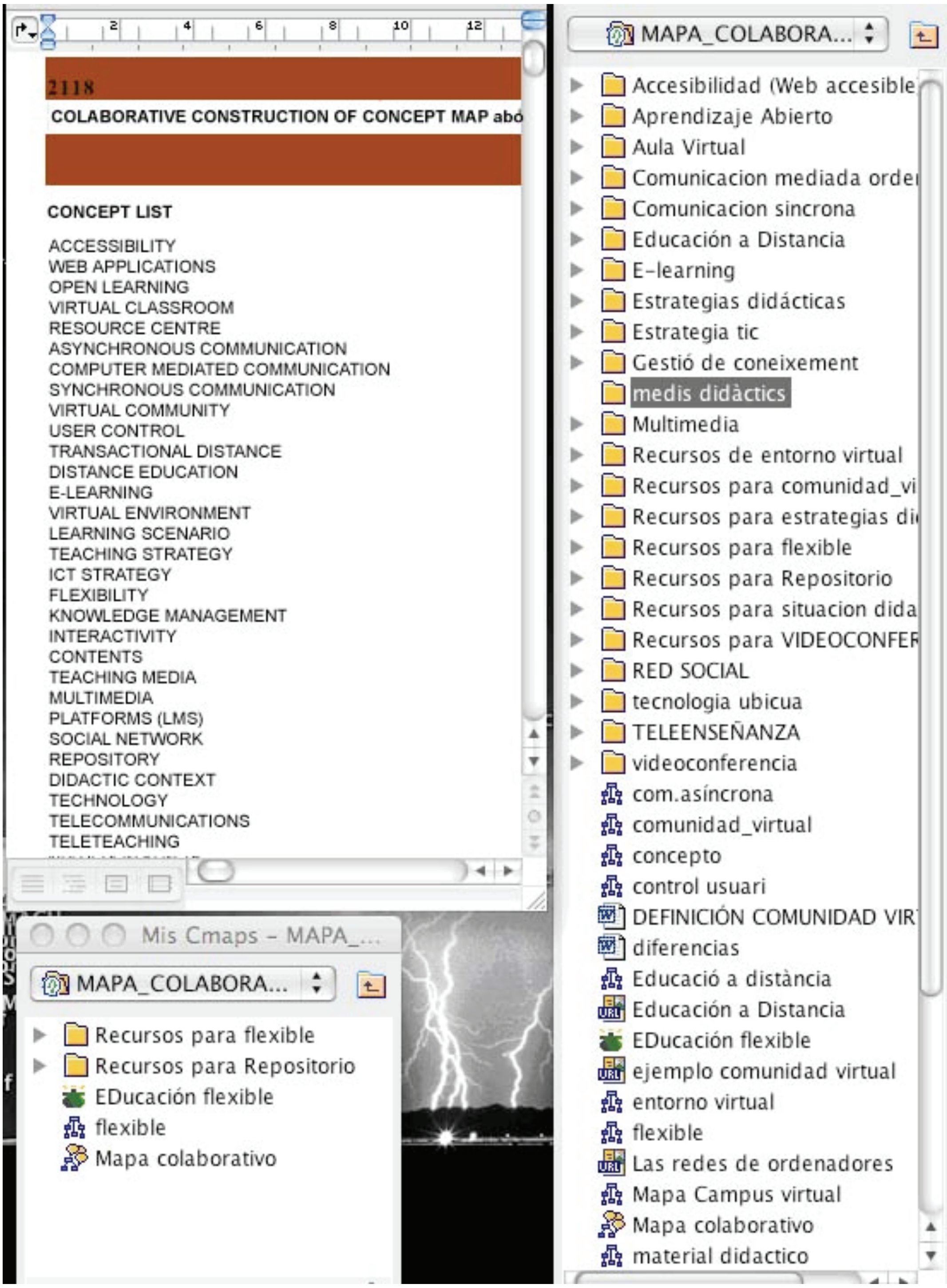

Figure 2.- The relation of main concepts assigned, and the initial and final folder of the project in the IHMC CmapServer.

Joint to the main concepts of the subject, a first map was provided to the students (Figure 3). They had to construct the collective map on it. The students had to construct the collective map on this by means of a process of negotiation of the connections between concepts.

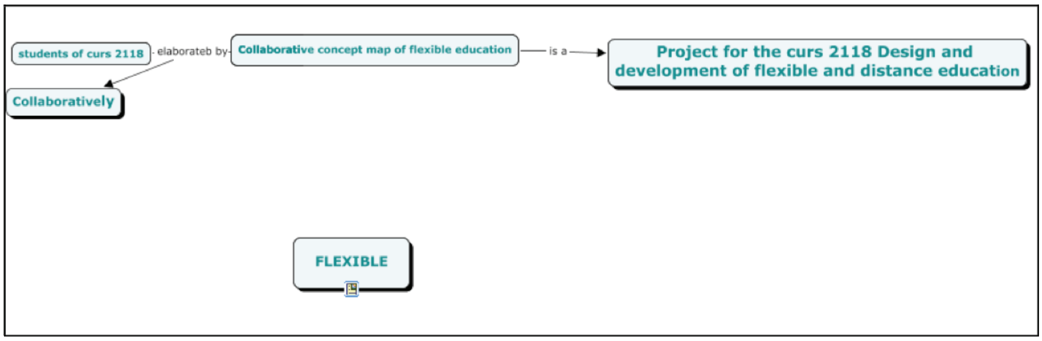

Figure 3. Initial map provided to the students.

The concept map about Flexible Education was constructed and reconstructed by the students on a process of collaborative learning where it was required the direct activity of each of the members of the group.

The process was developed following one double strategy of instruction: Concept map and collaborative learning. The use of the network in the project, has promoted so much the knowledge in itself, like the capacity to learn to learn.

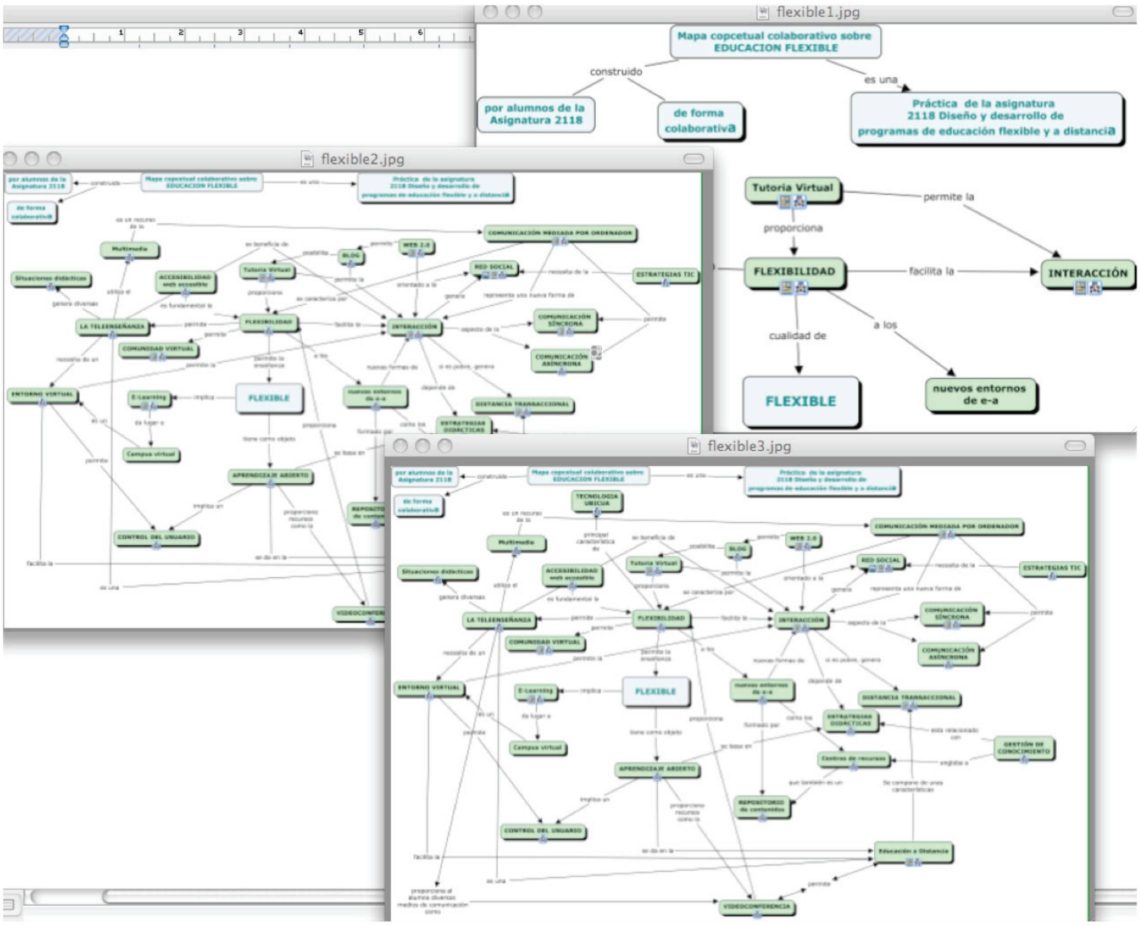

Figure 4. Evolution in the process of elaboration of the collective map (Week 1 to 4).

The elaboration of the concept map allows to organize the new information and to connect it with the already existing one. It was a step-by-step process. The final structure of the Concept map and the interconnection of the maps of each one of the concepts were been from a process of discussion, negotiation, exchange and reflection on the own work and the contributions of the others. The maps was linked between them, forming the representation of the group's knowledge (Figure 5).

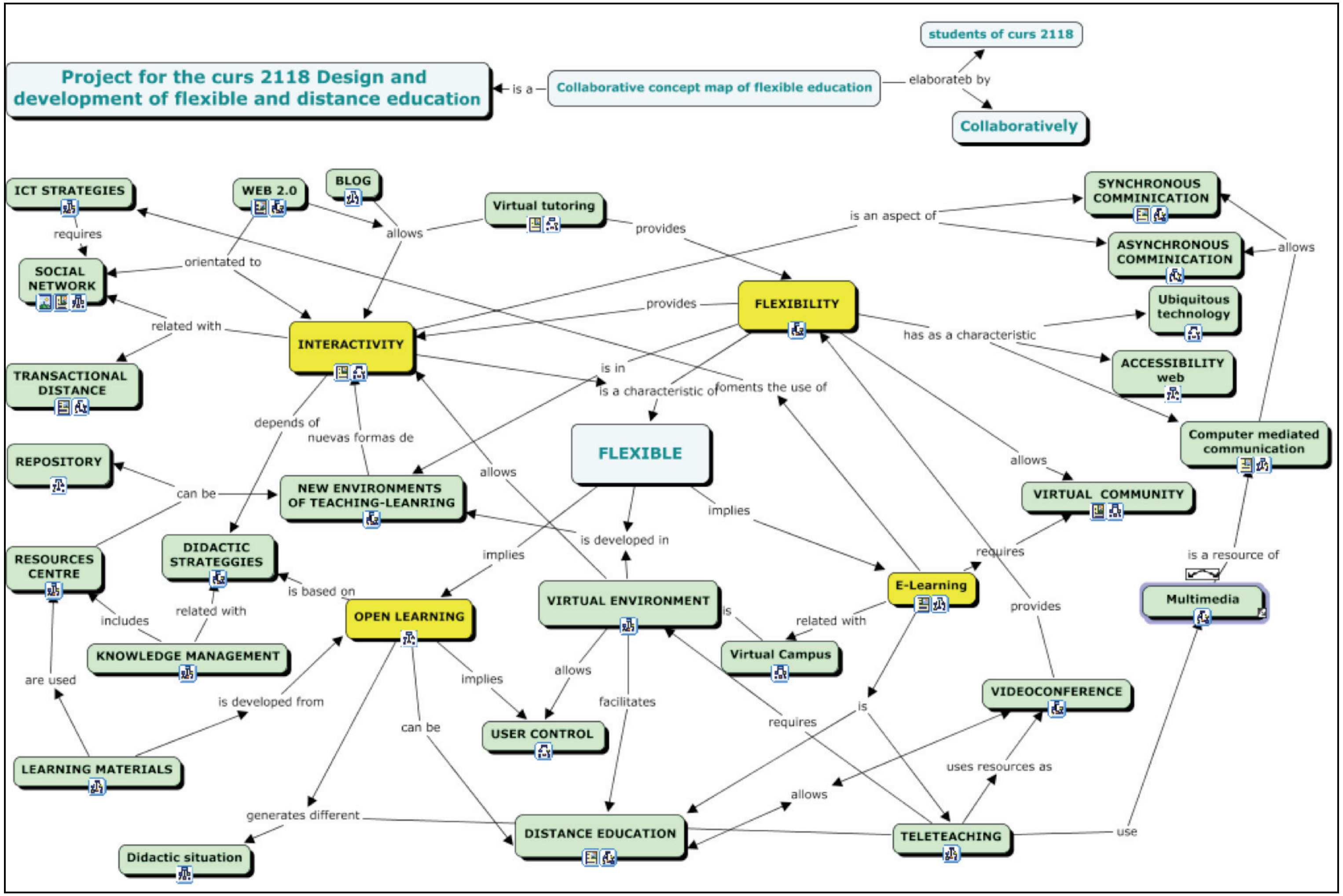

Figure 5. Definitive collaborative Concept map about Flexible Education.

The lack of communication between the members of the group caused that the definitive Concept map did not present a coherent and clear structure. The collective map was not sufficient to discuss, depurate and organise, and consequently it would not be definitive and could include concepts or connections erroneous. In the present situation of the map, their correction and discussion can serve as point of beginning for a future course.

3 Conclusions

In this experience, the Concept map and its elaboration through the suitable software is considered, as it is done it has developed taking as departure Jonassen (2000) a cognitive or mental tool. When it is used to develop abilities of the critic thought, which for this author consist on a group of abilities that cover the critic thought as such (analysis, evaluation and connection) the creative thought (elaborate, synthesise and imagine) and the complex thought (design, solve problems and take decisions).

From the developed experience, we can extract some reflections, although never definitive.

Own experience relation:

- In general, the students have had difficulties for the collaborative learning, had mainly to the lack of experience in this type of activity, and it was necessary at the beginning of the second stage, remember them what the work supposes in the group and its fulfilment of one of the project in common (share knowledge, strategies of communication, exchange of information,…)

- The list of discussion associated to the Concept map was not used at all. In its place of negotiation, the exchange, etc., it was developed in the forum of the course on MOODLE of the virtual environment and also face-to-face exchanges.

- The proposed term for the activity was not sufficient to discuss, depurate and organise the collective map, so we can say that the final presented work has not been ripened enough, and consequently it would not be definitive.

- The main problem, associated to the collaborative learning, was the insufficiency or deficiency of communication between the members of the group, which caused that the definitive Concept map did not have a coherent and clear structure for its later use like didactic element.

Related to the learning

- The students have used the tool to represent and express the models of each concept and to interrelate each of the Concept maps in a collective map, allowing the constructive critic and promoting the collaboration between them.

- Having to organise the resources through the Concept maps, the students must show a good domain on the subject (in this case the assigned concept), they contribute to improve the process of selection, assimilation, organisation and expression of the elements of the Internet to integrate them in their own material, having to dedicate time to the understanding of the concept.

- The mood of the maps to organise the information provide that the groups of the students should collaborate in the creation of the complex models, in which contents can be added with the time. The maps are easily linked between them, forming the representation of the group's knowledge. This facility complements the atmosphere of the collaboration on the construction of the Concept maps.

- The student constructs and reconstructs the knowledge supporting it on the process of collaborative learning where it is required the direct activity of each of the members of the group. The 'active learning' is developed in a non-competitive group, in which all the members of the group contribute to the learning of the rest, collaborating on the construction of the knowledge.

- This activity, in addition has allowed the students to learn to develop new abilities of communication supported by the new technologies and the handling of network tools for the collaborative work.

- The use of Concept maps as learning strategy foments the metacognitive reflection of the student on their own process of learning, helping him to regulate and to control this learning. Therefore, the collaborative construction of the Concept map foments, this way, a joint reflection and the coresponsibility of the final result.

- These methodologic strategies have cultivated in the students as much "the know that", like "the knowledge how", through the use of Internet as tool of research and the applications to collaborative work by means of Concept maps.

In relation to the product:

- The elaborated collective map, although we should consider that it is not definitive, constitutes a valuable resource for the following course. It will allow us to advance it, complete it, discuss it and improve it.

- When specifying how the different concepts of the subject are related, have contributed – and will contribute – to filter and depurate the thought when contributing to the comprehension of the new concepts and, in consequence, to integrate new knowledge.

- Just as the structure of the collective map is presented and the different maps of each of the concepts, as far as it concerns the presence of them as the consistency of the links, they contribute to identify Concept mistakes, errors on comprehension, etc.

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CONCEPT MAP GENERATION FROM OWL ONTOLOGIES

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Abstract. The paper is dedicated to concept map generation from OWL ontologies. This is an important issue because creation of concept maps for knowledge assessment tools are time and effort consuming. During last years since ontology description language OWL is developed amount of created ontologies have been extremely increased. A lot of ontologies written in OWL are freely available on Internet and could be reused as a base for concept maps. Therefore these resources may be effectively used if corresponding algorithms and tools are available. The paper presents algorithms for concept map generation from OWL ontology. The proposed algorithms are implemented into a software tool which is tested for concept map generation.

1 Introduction

Concept mapping has become quite popular and is applied to different areas, for example, knowledge management (Coffey, 1999), system analysis (Freeman, 2004), and as a research tool in educational science (Markham et al., 1994). Concept maps as a specific kind of mental models play a significant role in educational settings. Concept maps have proven their value for single and collaborative learning (Novak & Gowin, 1984; Cicognani, 2000), and for student knowledge assessment and self-assessment (Ruiz-Primo, 2004; Anohina et al., 2006). Due to the focus of this paper let's highlight only the usage of concept maps for knowledge assessment and self-assessment. The concept mapping approach offers a reasonable balance between requirements to assess a learner's knowledge at higher then fourth level of Bloom's taxonomy (Bloom, 1956) and implementation complexity of computer-based assessment system. Concept maps are used for representation and measuring of individual's knowledge by visualization of a graph, i.e., concept maps are graphs which nodes and arcs represent concepts and relationships between them, respectively (Croasdell et al., 2003).

Usually concept maps are represented as hierarchies with most general concepts at the top, and more specific concepts at lower levels (Novak & Canas, 2006). Concept maps can have different topologies, such as linear, circular, hub/spoke, tree and network/net (Yin et al., 2005). A wide variety of concept maps is an additional reason why knowledge assessment tools are based on concept maps (Ruiz-Primo, 2004; Anohina et al., 2007), because they offer a wide variety of different tasks. Concept map building tasks range from high-directed to low-directed depending on information provided for students. All tasks may be divided into fill-in tasks (high-directed) where concept map's structure is given and construction tasks (low-directed) where students themselves must create a concept map's structure (Ruiz-Primo, 2004).

Concept map based tasks as test items for assessment allows seeing student's cognitive structure, i.e., their knowledge structure. Thus, concept mapping promote system thinking which frequently is a critical point for students. Yet more, the use of concept maps supports a process oriented learning, in which a teacher divides a study course into several stages, i.e., logically complete parts, for example, topics (Anohina et al., 2006). Thus, a systematic assessment is supported, which, in its turn, allows to change teaching strategies and the learning content timely depending on results of assessment.

Concept maps are quite similar with ontologies which usage in computer science during last two decades has been rapidly increased. The most important step in ontology evolution is the development of Web Ontology Language (OWL) in the year 2004 (Bechhofer et al., 2004). OWL development together with many tools for ontology construction (Protégé, WebODE, OntoStudio etc.) made ontologies quite widespread and the number of available ontologies is fastly growing. On the Internet there are more than 83 000 ontologies encoded in OWL (searched using www.google.com in June, 2008) comparing with 58 000 in April, 2008 and 33 000 in September, 2007.

Ontologies are used in computer based tutoring systems for several purposes. Representation of a particular subject (Vergara Ede & Capuano, 2003; Bakhtyari, 2006), curriculum (Doan & Bourda, 2006) and student model (Aroyo & Dicheva, 2002) are only some examples. Such intelligent tutoring systems as FLUTE (Devedzic et al., 2000) and SlideTutor (Crowley et al., 2003) use several ontologies mainly in pedagogical and expert modules. The use of ontologies in education follows several goals. First, an ontology like a concept map represents a knowledge structure. Second, an ontology may support reasoning for diagnosis of causes of learner's mistakes and misconceptions, which is a relevant functions of student diagnosis module. Moreover, each item of the ontology may be supplied with references to corresponding learning objects which may be used by students to correct their mistakes. Third, an ontology can represent not only definite concepts and semantics of their relationships but also all synonyms of both. This may rise flexibility and adaptability of knowledge assessment allowing students to use synonyms. And last, but not least, at the moment on the Internet there are available quite a lot ontologies that correspond to taught subjects. Their usage may help teachers who are creating courses to reach compatibility of the knowledge structure they wanted to create with corresponding ontology. Our experience confirms that for teachers it is much easier to edit a concept map generated from an ontology or even to build it from scratch instead of mastering formal ontology languages and specific tools for ontology construction. Especially this is important for teachers who already use knowledge assessment tool based on concept maps (Anohina & Grundspenkis, 2007; Anohina et al., 2007).

Survey of literature showed that the basic technology for ontology transformation to other formats is based on metamodels. There are already defined metamodels for mapping from UML (Unified Modelling Language) to OWL, from OWL to UML, from OWL to Topic Maps, from Topics Maps to OWL, from OWL to Common Logic within Meta-Object Facility Query/View/Transformation framework (OMG, 2006; Na et al., 2006). Algorithms for ontology transformation into schema of relational database also are worked out (Vysniauskas & Nemuraite, 2006). Transformation from ontology to concept map and vice versa is implemented in COE tool (http://cmap.ihmc.us/coe) for ontology visualization, editing and building using concept maps. However, this tool is not suitable for the developed knowledge assessment system (Anohina & Grundspenkis, 2007; Anohina et al., 2007) due to following reasons. First, its user interface and automatically added names of links and nodes (such as “is a”, “are”, “(DataTypeProperty)”, “Things which”, etc.) don’t support Latvian language. Second, the full functionality of COE, for example, various restrictions on values, cardinalities, etc. is not necessary for concept maps used for knowledge assessment. Third, the transformation tool must be compatible with already developed knowledge assessment system.

The remaining of the paper is organized as follows: in Section 2 similarities between OWL ontologies and concept maps are outlined. Proposed algorithms for concept map generation from OWL ontology is described in Section 3. In Section 4 testing results of concept map generation tool in which proposed algorithms have been implemented are given. Finally, some conclusions and future work is outlined.

2 Similarities between OWL ontologies and concept maps

Both ontologies and concept maps represent some domain. Both have classes or concepts and relations between them. Unlike concept maps ontologies have also attributes for classes, their values and restrictions on them. In other words ontologies are more expressive. At the same time concept maps also could represent the same more expressive features using only concepts and links between them. Since ontologies are described using special languages, such as OWL (Bechhofer et al., 2004), DAML+OIL (van Harmelen et al., 2001), Ontolingua (Gruber, 1992), or special knowledge structure like frames correspondence between ontology elements and concept map elements should be defined.

Mappings between main elements of OWL ontology and elements of the concept map are shown in Figure 1. Main elements of OWL ontology which correspond to the concept are a class, an instance, a datatype property, its value and a type of value, while an object property corresponds to a link. An object property is semantic relation between classes or instances.

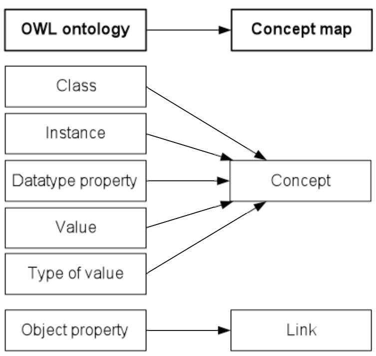


Figure 1. Correspondence of main ontology elements to concept map elements

However, OWL ontology has also other constructions to define elements which could be transformed as concept map elements. OWL constructions and corresponding concept map elements are summarized in Table 1.

#	OWL elements	Concept map elements	#	OWL elements	Concept map elements
1.	`owl:Class`	Concept	7.	`owl:FunctionalProperty`	Link
2.	`owl:DatatypeProperty`	Concept	8.	`owl:InverseFunctionalProperty`	Link
3	`owl:DeprecatedClass`	Concept	9.	`owl:ObjectProperty`	Link
4.	`owl:DeprecatedProperty`	Link	10.	`owl:SymmetricProperty`	Link
5.	`owl:equivalentClass`	Class	11.	`owl:TransitiveProperty`	Link
6.	`owl:equivalentProperty`	Link			

Table 1. Correspondence of specific OWL elements to concept map elements

Along with links retrieved from object properties additional links are introduced:

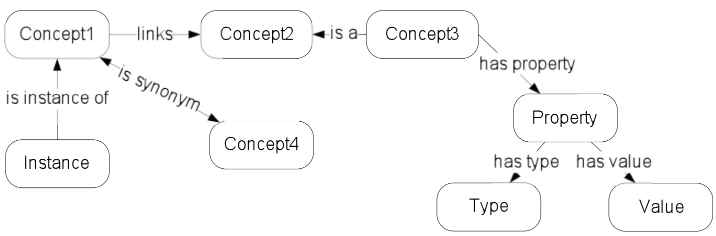
- “is a” to represent hierarchal relation between two classes;
- “is instance of” to represent relation between a class and its instances;
- “is synonym” to represent that two classes/instances are synonyms;
- “is not” to represent that two classes are complement;
- “has property” to present relation between a class/instance and a datatype property;
- “has type” to present relation between a datatype property and a data type of its value;
- “has value” to present relation between a datatype property and its value.

Mentioned additional links are needed to represent relations between concepts in the concept map which are described using specific constructions in the ontology. Detailed information about these constructions can be found in (Graudina, 2008).

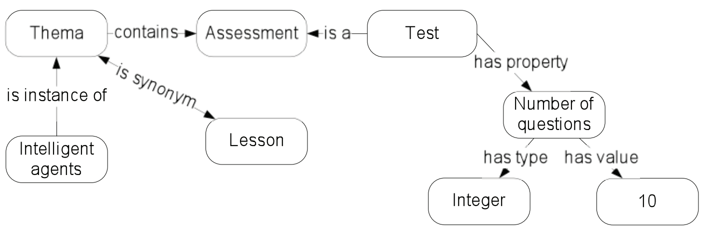
3 Algorithm for concept map generation from OWL ontology

In this section the concept map generation algorithm is described. There is a need for text analyzer (a parser) to mine information from an ontology described in OWL, which is saved as text in *.owl. The parser mines concept names and their relations analyzing *.owl file. The algorithm used by the parser is described in this section.

Information mined from ontology is stored in an incidence matrix, where names of concepts and relations between concepts (the names of the links and direction of the links) are stored. An example of an abstract concept map is shown in Figure 2a). The concrete example for the abstract concept map is given in Figure 2b). The corresponding incidence matrix for the abstract concept map is given in Table 2.



a)



b)

Figure 2. Example of concept maps a) abstract, b) concrete

Name of concept	Concept1	Concept2	Concept3	Concept4	Instance	Property	Type	Value
Concept1		link		is synonym				
Concept2								
Concept3		is a				has property		
Concept4	is synonym							
Instance	is instance of							
Property							has type	has value
Type								
Value								

Table 2. The incidence matrix

Basic steps for concept map generation from an ontology are the following:

1. Read an ontology file and check OWL syntax.
2. Find all classes (begin creating of incidence matrix).
3. Find subclasses of each class (for particular class add link "is a" which goes from subclass to superclass in the matrix).
4. For each class check equivalence and similarity (add link "is synonym" in the matrix).
5. For each class check intersection and union to other classes (add link "is a" in the matrix).
6. For each class check complement relations to other classes (add link "is not" in the matrix).
7. Find instances of each class (add instances and links "is instance of" between appropriate classes and instances which go from a instance to a class to the matrix).
8. Find datatype properties for each class and instance (add properties and links "has property" between appropriate class/instance and a property to the matrix).
9. Find values for each datatype property (add properties' values and links between a datatype property and its value "has value" to the matrix).
10. Find types for datatype property's values (add a value's type and a link between a datatype property's value and its type to the matrix).
11. Find object properties for each class/instance (add appropriate links between classes or instances to the matrix).
12. Check if an object property is symmetric or transitive (extend the matrix with appropriate links).
13. Perform correction of concept and link names (replace understrike sign "_" with space).
14. Display completed incidence matrix as a graph.

At first, the teacher chooses an ontology for concept map generation, then the concept map generation software performs all transformations and displays a generated concept map. Before transformation actions verification of chosen *.owl file is performed to check correctness of used OWL syntax. If the ontology doesn't conform OWL syntax, the teacher receives an error message. If verification is successful the concept map generation algorithm starts. In the beginning all classes, their hierarchy and instances are found, afterwards datatype properties, their values and types are found, and at the end object properties are found. Finally, correction of concept and link names is performed and generated concept map is displayed to the teacher.

For simpler implementation previously mentioned algorithm's steps are merged in the following way: transformation of ontology classes and instances (steps 2, 3, 4, 5, 6, 7), transformation of datatype properties, their values and types (steps 8, 9, 10), transformation of object properties (steps 11, 12).

The first step of the concept map generation algorithm is to find a class hierarchy and its extension with instances of classes (see Figure 3). At first the root class is found, and a class name is added to the incidence matrix. Then it is checked if the class has instances. If yes, then names of instances are added to the matrix as well as the link "is instance of" to relate instances with the root class. If the root class hasn't instances, it is checked if it has subclasses. If yes, then the names of subclasses are added to the matrix as well as the link "is a" to relate the root class with subclasses. Each subclass is checked if it has instances and subclasses similarly as in case with the root class. Based on the results of checking the matrix is updated. Instances of the class are mined before subclasses due to simpler recursion programming needed for mining. After all classes have been found they are checked to mine additional information. Classes are checked if they have synonym classes. If yes, then the matrix is updated with the link "is synonym" between synonym classes. Then classes are checked if they are result of intersection or union of other classes, if yes, then in case of intersection the link "is a" is added from the class to other classes from intersection, in case of union the link "is a" is added from classes from union to the class.

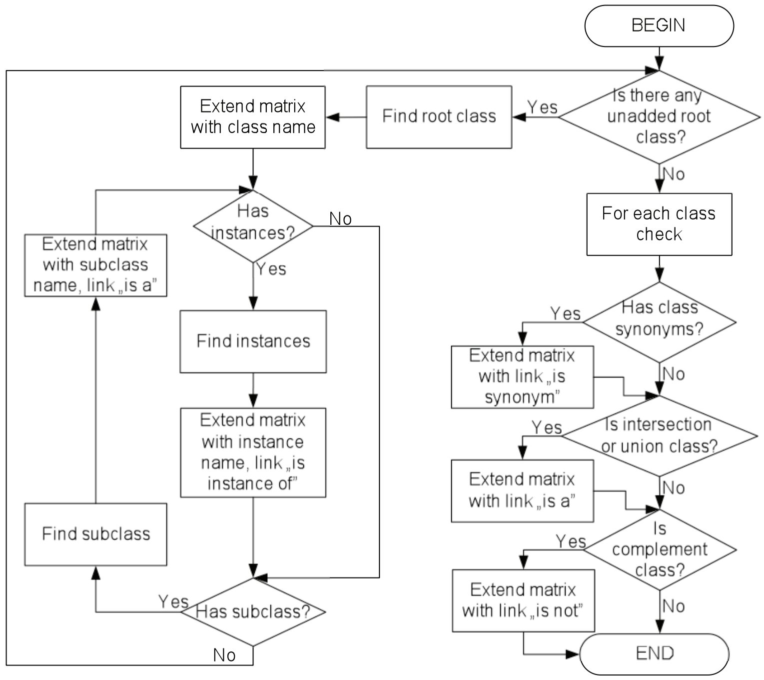


Figure 3. Transformation of ontology classes and instances

The next step is to find datatype properties, their values and types of values (see Figure 4). First, datatype properties are found for each class. The matrix is updated with names of datatype properties, as well as the link "has property" at the appropriate class. Then for each datatype property it is checked if allowed values for this property are defined. If there are such values, their names are added to the matrix, as well as the link "has value" at the datatype property. If the type of values is defined, it is also added to the matrix and the link "has type" at the appropriate datatype property. For each class which has datatype property it is checked are some of defined allowed values assigned to its instances. In case if any of values are assigned to the instance the link between the class and this value is deleted and added between the instance and the value, i.e., the value becomes local, it is related only to the instance.

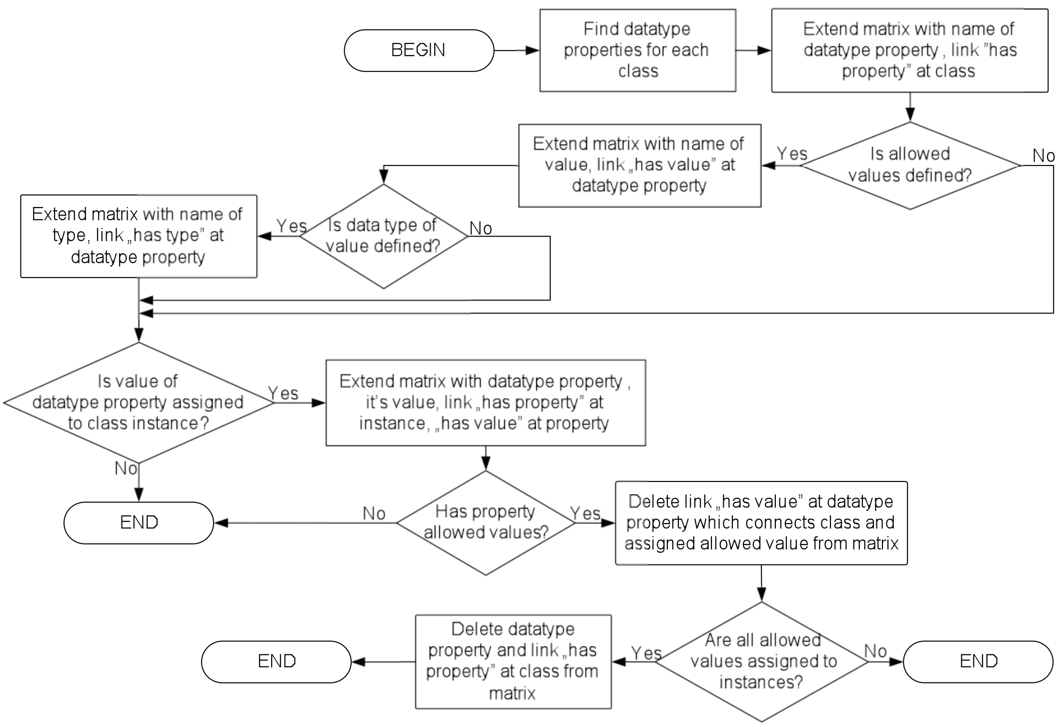


Figure 4. Transformation of datatype properties, their values and types of values

The next step after datatype property mining is object property mining. In this step semantic relations between classes and their instances are found. First, all object properties between classes are found, then domain and range classes for object properties are found and links (names of object properties) at domain classes are added to the matrix. If the object property is symmetric then the link is added also at the range class. Then it is checked if the object property is transitive. If yes, then the link is added at the "transitive" class, for example, if the class A is linked to the class B and the class B is linked to the class C, then in the matrix also the link between A and C is added, and the class A is the "transitive" class. Checking of object property's symmetry and transitivity provides the concept map with additional links, that is, in case of the symmetric link the link in the concept map is bidirectional and in case of transitive link the third inferred link is added to the concept map. Second, object properties between instances are found. Then the matrix is updated with links between instances. However, links between superclasses of instances are deleted. Characteristic of symmetry and transitivity is checked, too. The realization of this step is shown in Figure 5.

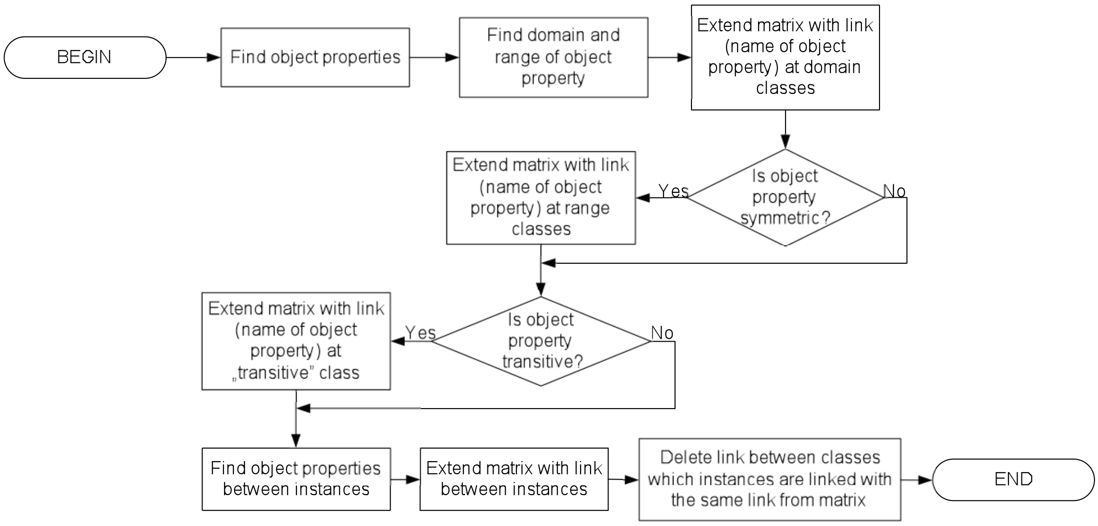


Figure 5. Transformation of object properties

Before the matrix is displayed as concept map correction of concept and link names are performed, i.e., the understrike sign "_" is replaced with space. Correction is needed because OWL doesn't support space sign in the element names, and the world practise is to replace space sign with understrike sign "_" in OWL code, and for concept map visuality it is replaced back.

4 Implementation and testing

Proposed algorithms for concept map generation have been implemented in software. Concept map generation tool is implemented using programming language Java and application programming interface Jena (available at: http://jena.sourceforge.net/) for accessing *.owl files and parsing OWL elements. For class hierarchy and instance mining reasoning mechanisms build in Jena are used.

The developed tool was tested using 10 ontologies of the computer science field. It was unable to generate concept maps from two ontologies due to errors in OWL syntax. Two concept maps were generated with unnecessary concepts. The authors of these ontologies have used a special mode of the ontology development tool called Protégé, i.e., frame mode (available at: http://protege.stanford.edu). Series of special concepts used only in this mode are added to created ontologies. These unnecessary concepts are such as DIRECTED-BINARY-RELATIONS, PAL-RANGE, PAL-NAME, PAL-DESCRIPTION, PAL-STATEMENT, etc. which are needed to support inner structure of frames used in Protégé. So, six concept maps are successfully generated with the developed tool. One example of concept map generated using the developed tool is shown in Figure 6.

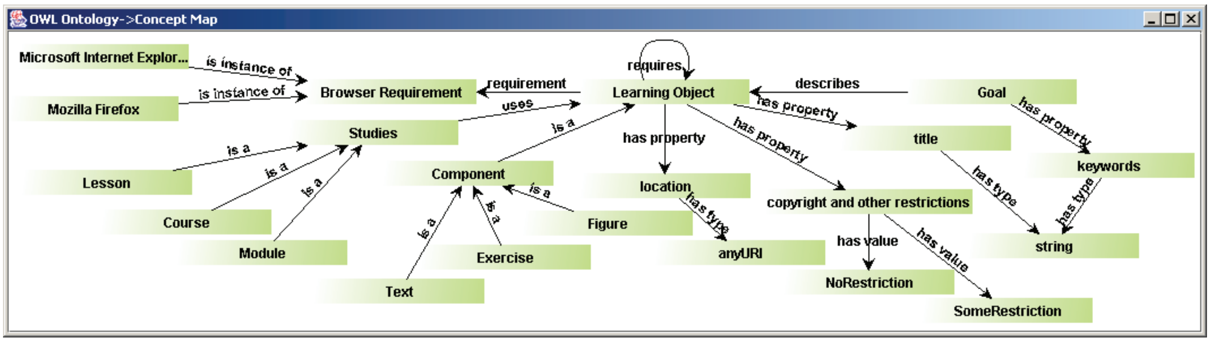


Figure 6. Generated concept map

5 Conclusions and future work

Concept maps and ontologies both represent knowledge structures and may be used to promote system thinking. Concept maps have proved their usefulness in teaching and learning process, in particular, for knowledge assessment and self-assessment. Concept maps promote process oriented learning and systematic knowledge assessment. Ontologies may increase flexibility and adaptiveness of knowledge assessment systems to each individual learner. Moreover, ontologies made a concept map construction tasks easier for teachers, and may help them to discover unrelated parts in a concept system of their courses.

In this paper algorithm for concept map generation from OWL ontologies is presented. The proposed algorithm is based on defined similarities between elements of OWL ontology and elements of the corresponding concept map. The concept map generation tool has been implemented using programming language Java and application programming interface Jena. Testing results of the tool confirmed its suitability for concept map generation.

Future work is related to further refinement and enhancement of concept map generation software. First task is to eliminate drawback connected with ontologies made in frame mode of ontology construction tool Protégé. It is valuable for concept map generation tool that all ontologies described in OWL could be transformed into concept maps independently from their construction tool. Then concept map visualization should be improved by adding graph visualization algorithms. And the most important task is to integrate the developed tool in already existing student knowledge self-assessment system based on concept maps (Anohina et al., 2006; Anohina et al., 2007). Also, it is planed to create the ontology repository for teachers where subject ontologies in Latvian will be stored.

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CONCEPT MAPPING & VEE DIAGRAMMING A PRIMARY MATHEMATICS SUB-TOPIC: "*TIME*"

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A case study investigated a primary preservice teacher's use of concept mapping to interpret 'time' syllabus outcomes of a primary mathematics curriculum and vee diagrams to analyse problems. Findings suggest the preservice teacher developed enhanced skills to critically analyse a topic and a problem. She competently provided mathematical justifications for methods in terms of principles and concepts that are appropriate for primary students, which reflected her developing pedagogical content knowledge and understanding of syllabus outcomes. Constructing concept maps and vee diagrams enabled the preservice teacher to effectively communicate her mathematical ideas, and as a result, developed a deeper, conceptual understanding of the developmental and sequential nature of the mapped sub-strand across the different stages of primary mathematics. Implications for teaching primary mathematics are provided.

1 Introduction

The underlying principles of the New South Wales Board of Studies' *K-6 Mathematics Syllabus* (NSWBOS, 2002) encourage teachers to develop students' conceptual understanding through an appropriate sequence of learning activities and implementation of working mathematically strategies in the classroom. Hence preservice teachers need to develop deep understanding of the mathematics they are expected to teach their future students. To facilitate the development of a primary preservice (PPS) teacher's deep understanding of a syllabus, a case study was conducted to examine the usefulness of the metacognitive tools of hierarchical concept maps (maps) and vee diagrams (diagrams) as means of facilitating conceptual analyses of syllabus outcomes and mathematics problems. For this paper, the focus question is: "*In what ways do hierarchical concept maps and vee diagrams facilitate the development of a primary preservice teacher's deep understanding of the syllabus outcomes of the time sub-strand*?" The Bachelor of Education PPS teacher (i.e., Susan) concept mapped and vee diagrammed over a semester, in her third year mathematics education course in a regional Australian university.

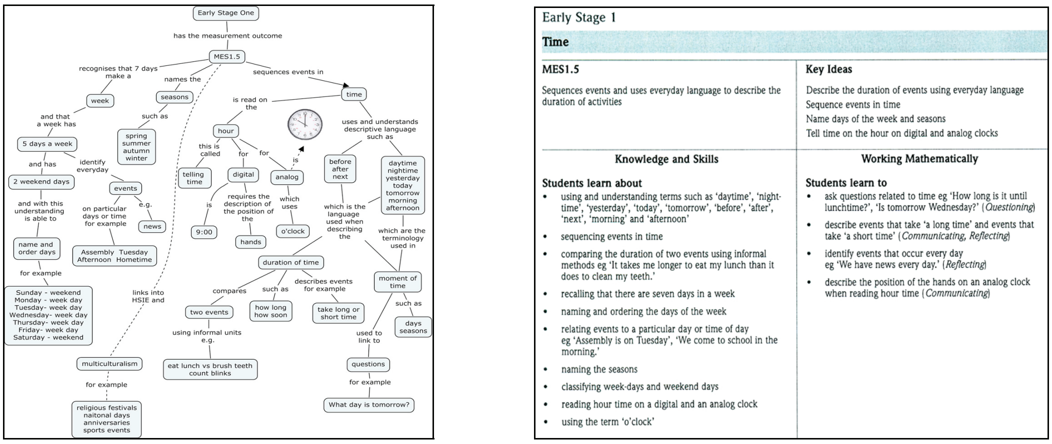
Ausubel's theory of meaningful learning, which defines meaningful learning as learning in which students actively make connections between what they already know and new knowledge, underpins concept mapping particularly its principle that learners' cognitive structures are hierarchically organized with more general, superordinate concepts subsuming less general and more specific concepts. Linking new concepts to existing cognitive structures may occur via *progressive differentiation* (reorganization of existing knowledge under more general ideas) and/or *integrative reconciliation* (synthesising many ideas into one or two when apparent contradictory ideas are reconciled) (Ausubel, 2000; Novak & Cañas, 2006). Others (Jonassen, Peck & Wilson, 1999; Wiske, 1998) also argue that for learning to be meaningful, students must be actively engaged with the learning activity, know their learning goals, construct and reflect on the activity and interpret the results, and self-monitor their progress towards their goals. Further, each discipline has its main concepts and ideas and methods of inquiry. As students seek out interconnections at both the conceptual and procedural levels, they create meaningful relationships and continually reinforce their understanding, which should guide them to solve challenging problems and conduct investigative activities. As an analytical and learning tool, hierarchical concept maps, first introduced by Novak to unpack students' understanding of science concepts based on analyses of interview transcripts, are used to illustrate the hierarchical interconnections between main concepts (nodes) of a knowledge domain with descriptions of the interrelationships (linking words) on the connecting lines. The basic semantic unit (*proposition*) describes a meaningful relationship as shown by the triad "valid-node→valid-linking-words→valid node" (Novak & Gowin, 1984). Vee diagrams, in contrast, were introduced by Gowin as an epistemological tool, in the shape of a vee that is contextualised in the phenomenon to be analysed, as a means of guiding the thinking and reflections involved in making connections between methods of inquiry and the structure of a discipline. The vee's left side depicts the philosophy and theoretical framework driving the analysis to answer the focus question. On the vee's right side are the records, methods of transforming the records to answer the focus question and value claims. The epistemological vee was later modified (Afamasaga-Fuata'i, 2005, 1998) to guide the thinking and reasoning involved in problem solving (an example is presented later). Uses of concept maps and/or vee diagrams as assessment tools of students' conceptual understanding have been examined over time in the sciences (Novak & Cañas, 2004; Mintzes, Wandersee & Novak, 2000) and mathematics (Afamasaga-Fuata'i, 2004, 1998; Hannson, 2005; Williams, 1998). Investigations of the usefulness of maps/diagrams found students' mapped knowledge structure became increasingly complex and integrated as a consequence of multiple iterations of social critiques, revisions and presentations over the semester (Afamasaga-Fuata'i, 2007, 2004). Others also demonstrated the value of maps as pedagogical planning tools to provide topic overviews (Brahier, 2005; Afamasaga-Fuata'i, 2006; Afamasaga-Fuata'i & Reading, 2007), and the usefulness of diagrams to scaffold students' thinking and reasoning and to illustrate interconnections between theory and application in mathematics problem solving (Afamasaga-Fuata'i, 2007, 2005), scientific inquiry (Mintzes, Wandersee & Novak, 2000) and epistemological analysis (Novak & Gowin, 1984).

2 Methodology, & Data Analysis

The case study began with a familiarisation phase, which introduced Susan to the metacognitive strategies using simple topics such as fractions and operations with fractions. Constructing a comprehensive, hierarchical concept map of a mathematics topic selected from the primary mathematics syllabus, and diagrams of related problems to demonstrate the applications of the mapped concepts was the required project of the course. There were three phases to the project. Phase 1 (Assignment 1) required that Susan compile an initial list of concepts, based on a conceptual analysis of the relevant syllabus outcomes, and then to construct an initial topic concept map and diagrams of problems. These were presented and critiqued in class before returning for further revision and expansion. Phase 2 (Assignment 2) involved the presentation of a more structurally complex, expanded concept map and diagrams of more problems. These were socially critiqued and returned for further revision and expansion. Phase 3 (Assignment 3) was the final submission of a more comprehensive, hierarchical topic concept map and more diagrams of related problems and activities, which extended previous work and incorporating comments from previous critiques, and including a journal of reflections. Data collected included maps and diagrams from the familiarization phase, weekly workshops, and three phases of the main project including a journal of reflections. This paper presents samples of Susan's submitted work in Phase 1 to illustrate the application of maps/diagrams as learning, analytical and pedagogical tools for the *Time* sub-strand of the *NSW BOS K-6 Mathematics Syllabus* (NSWBOS, 2002). Her work with the *Area* sub-topic of the measurement content strand is reported in Afamasaga-Fuata'i (2007). Susan's concept maps illustrate her critical analyses and interpretations of the *Time* Knowledge & Skills (K&S) and Working Mathematically (WM) Syllabus Outcomes from *Early Stage One to Stage 4*, and an example vee diagram explicating her critical analysis of a mathematics problem. Concept maps are qualitatively analysed by considering the meaningfulness and interconnectedness of the networks of propositions each displays and qualitatively compared to statements of syllabus outcomes. For this paper, concept maps are read from top to bottom in following a link and across from left to right for branches unless otherwise specified. Excerpts from Susan's reflection journal are also provided to support her concept map and vee diagram data.

3 Syllabus Outcome Concept Maps

MES1.5 syllabus outcomes involve the introduction of the concepts of week, seasons and time as interpreted by Susan and viewed in Figure 1a. The leftmost branch focuses on elaborating a week as 5 days and 2 weekend days with the final node listing the names and type of days (week day or weekend). A progressive differentiating link from the 5 days a week node illustrates the identification of everyday events on particular days or time such as assembly on Tuesday and news. The adjacent branch focuses on naming the four seasons as illustrated. The rightmost branch comprises three sub-branches. The left sub-branch splits further into three smaller sub-branches. The first one describes the process of reading time on the hour as telling time, for digital (second sub-branch), an example is provided, it requires a description of the position of the hands, and for analog (third sub-branch), reading on the hour uses the term o'clock and the analog clock as provided. With the last two sub-branches of the time branch, examples are provided of the language used to describe time on the left (e.g., before, after, next) and the right (e.g., daytime, nighttime, …, afternoon) before integratively merging at the linking words and then progressively differentiating to two nodes, namely, duration of time on the left, and moment of time on the right. With progressive differentiating links from the former node, they illustrate the comparison of the duration of two events by using informal units (on the left) (e.g., eat lunch vs brush teeth), using question phrases (how long, how soon)(middle link) and using descriptive phrases such as take long or short time (right link). From the moment of time node are two progressively differentiating links, one illustrates the use of descriptive language to ask questions (e.g., What day is tomorrow?) and the other exemplifies that moment of time can be described in days or seasons. Also provided is a single link from the MES1.5 node at the top, which describes a connection to the HSIE subject and multiculturalism as illustrated by religious festivals, national days, anniversaries and sports events. HSIE, Human Society and its Environment, is one of the Key Learning Areas in New South Wales, Australian schools. Overall, this stage focuses on describing the duration of events using everyday language, sequencing of events in time, naming days of the week and seasons and telling time on the hour on digital and analog clocks. A comparison to the list of outcomes (Figure 1b) indicates that all of the key ideas and working mathematically strategies have been included as requested.



Early Stage 1

Time

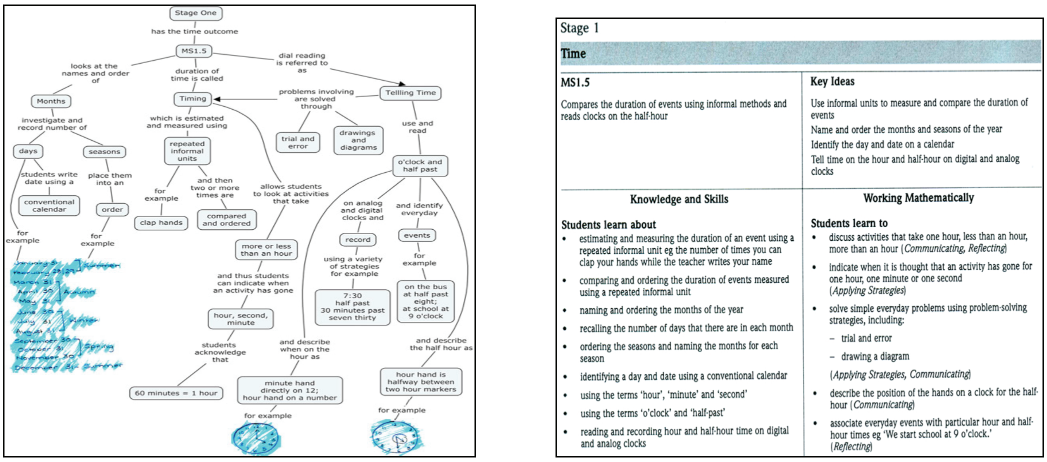
MES1.5	Key Ideas
Sequences events and uses everyday language to describe the duration of activities	Describe the duration of events using everyday language Sequence events in time Name days of the week and seasons Tell time on the hour on digital and analog clocks

Knowledge and Skills	Working Mathematically
Students learn about • using and understanding terms such as 'daytime', 'night-time', 'yesterday', 'today', 'tomorrow', 'before', 'after', 'next', 'morning' and 'afternoon' • sequencing events in time • comparing the duration of two events using informal methods eg 'It takes me longer to eat my lunch than it does to clean my teeth.' • recalling that there are seven days in a week • naming and ordering the days of the week • relating events to a particular day or time of day eg 'Assembly is on Tuesday', 'We come to school in the morning.' • naming the seasons • classifying week-days and weekend days • reading hour time on a digital and an analog clock • using the term 'o'clock'	**Students learn to** • ask questions related to time eg 'How long is it until lunchtime?', 'Is tomorrow Wednesday?' (*Questioning*) • describe events that take 'a long time' and events that take 'a short time' (*Communicating, Reflecting*) • identify events that occur every day eg 'We have news every day.' (*Reflecting*) • describe the position of the hands on an analog clock when reading hour time (*Communicating*)

(a) (b)

Figure 1. Concept map and Early Stage One Time syllabus outcomes (NSWBOS, 2002).

Provided in Figure 2a is a concept map of Susan's interpretations of the Stage One syllabus outcomes (MS1.5 in Figure 2b). It illustrates that the main concepts are months, timing and telling time, which build upon and extend concepts already introduced in the previous stage.



Stage 1

Time

MS1.5	Key Ideas
Compares the duration of events using informal methods and reads clocks on the half-hour	Use informal units to measure and compare the duration of events Name and order the months and seasons of the year Identify the day and date on a calendar Tell time on the hour and half-hour on digital and analog clocks

Knowledge and Skills	Working Mathematically
Students learn about • estimating and measuring the duration of an event using a repeated informal unit eg the number of times you can clap your hands while the teacher writes your name • comparing and ordering the duration of events measured using a repeated informal unit • naming and ordering the months of the year • recalling the number of days that there are in each month • ordering the seasons and naming the months for each season • identifying a day and date using a conventional calendar • using the terms 'hour', 'minute' and 'second' • using the terms 'o'clock' and 'half-past' • reading and recording hour and half-hour time on digital and analog clocks	**Students learn to** • discuss activities that take one hour, less than an hour, more than an hour (*Communicating, Reflecting*) • indicate when it is thought that an activity has gone for one hour, one minute or one second (*Applying Strategies*) • solve simple everyday problems using problem-solving strategies, including: – trial and error – drawing a diagram (*Applying Strategies, Communicating*) • describe the position of the hands on a clock for the half-hour (*Communicating*) • associate everyday events with particular hour and half-hour times eg 'We start school at 9 o'clock.' (*Reflecting*)

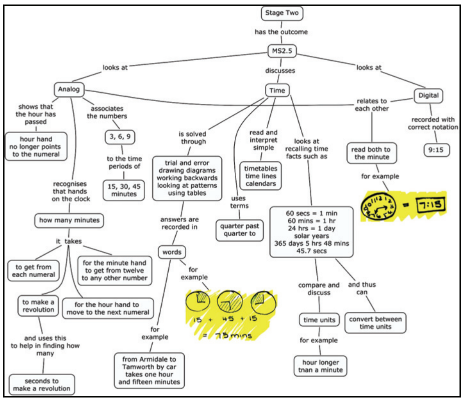
(a) (b)

Figure 2. Concept map and Stage One Time syllabus outcomes (NSWBOS, 2002).

The leftmost branch describes the number of days per month, names and order of months with a right sub-branch describing that students record days and write dates using a conventional calendar. Another sub-branch (to the right) records the number of seasons, names and order as shown by the branch's illustrative example. For the timing branch in the middle, the propositions describe that timing means duration of time and it is estimated and measured using repeated informal units when two or more times are compared and ordered. An example of informal units is clap hands. The adjacent sub-branch (to the right) describes that students consider activities that take more or less than an hour so that they can indicate when an activity is completed in terms of hour, second and minute based on the knowledge that 60 minutes is one hour. Two (timing and telling time) of the main concepts are cross-linked through the linking words (problems involving are solved through) and connecting to two illustrative methods of solving problems, namely, trial and error and drawings and diagrams. The rightmost branch describes that dial reading means telling time; it uses and reads o'clock and half past, and describes that the half hour is the hour hand halfway between two hour markers such as shown on the analog clock for four thirty. More progressively differentiating links from the o'clock and half past node, on the far left, describes the meaning of on the hour in terms of the position of the minute and hour hands as illustrated by the analog clock showing four o'clock. The adjacent sub-branch to the right describes that telling time using o'clock and half past on analog and digital clocks and recording these involve the use of a variety of strategies as illustrated. The adjacent sub-branch to the right illustrates the use of o'clock and half past to identify everyday events such as on the bus at half past eight and at school at 9 o'clock. Overall, Stage One continues to consolidate the use of informal units to measure and compare the duration of events; introduces months, identification of day and date on calendar, and half hour; and extends understanding of the seasons of the year and telling time on digital and analog clocks to using both hour and half hour. A comparison of the concept map

(Figure 2a) to the text of the syllabus outcomes (Figure 2b) reveals that all key ideas and working mathematically strategies have been accommodated.

Susan’s interpretations of the Stage Two syllabus outcomes (Figure 3b) showed that the main concepts are analog, time and digital as provided in Figure 3a. The leftmost sub-branch (Figure 3a) describes that, analog shows the hour has passed if the hour hand no longer points to the numeral. Four progressively differentiating links in the next sub-branch (to the right) illustrates that on the analog, the hands on the clock indicates how many minutes it takes to get from each numeral, to make a revolution and using the information to find how many seconds to make one revolution. The next link to the right focuses on number of minutes for the hour hand to move to the next numeral and the last link focuses on how many minutes for the minute hand to get from twelve to any other number.



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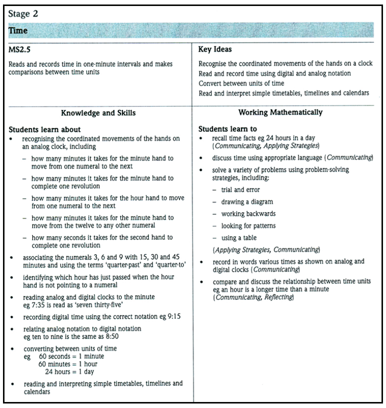


Stage 2

Time

MS2.5	Key Ideas
Reads and records time in one-minute intervals and makes comparisons between time units	Recognise the coordinated movements of the hands on a clock Read and record time using digital and analog notation Convert between units of time Read and interpret simple timetables, timelines and calendars

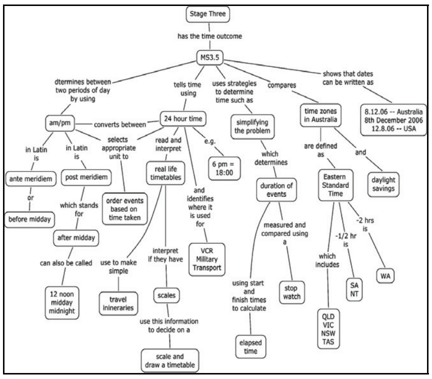
Knowledge and Skills	Working Mathematically
Students learn about • recognising the coordinated movements of the hands on an analog clock, including – how many minutes it takes for the minute hand to move from one numeral to the next – how many minutes it takes for the minute hand to complete one revolution – how many minutes it takes for the hour hand to move from one numeral to the next – how many minutes it takes for the minute hand to move from the twelve to any other numeral – how many seconds it takes for the second hand to complete one revolution • associating the numerals 3, 6 and 9 with 15, 30 and 45 minutes and using the terms ‘quarter-past’ and ‘quarter-to’ • identifying which hour has just passed when the hour hand is not pointing to a numeral • reading analog and digital clocks to the minute eg 7:35 is read as ‘seven thirty-five’ • recording digital time using the correct notation eg 9:15 • relating analog notation to digital notation eg ten to nine is the same as 8:50 • converting between units of time eg 60 seconds = 1 minute, 60 minutes = 1 hour, 24 hours = 1 day • reading and interpreting simple timetables, timelines and calendars	**Students learn to** • recall time facts eg 24 hours in a day (*Communicating, Applying Strategies*) • discuss time using appropriate language (*Communicating*) • solve a variety of problems using problem-solving strategies, including: – trial and error – drawing a diagram – working backwards – looking for patterns – using a table (*Applying Strategies, Communicating*) • record in words various times as shown on analog and digital clocks (*Communicating*) • compare and discuss the relationship between time units eg an hour is a longer time than a minute (*Communicating, Reflecting*)

(b)

Figure 3. Concept map and Stage Two Time syllabus outcomes (NSWBOS, 2002).

At the top of the analog branch is a sub-branch describing the association of the numbers 3, 6, and 9 with the periods of 15, 30 and 45 minutes. The middle, time branch shows a left sub-branch describing that solving for time involves multiple methods such as illustrated where the answers are recorded in words (e.g., from Armidale to Tamworth by car takes one hour and fifteen minutes) or using analog clock diagrams and numbers as illustrated by the example. The sub-branch (to the right) describes the use of terms such as quarter past and quarter to with the adjacent sub-branch focusing on reading and interpreting simple timetables, time lines and calendars. The rightmost sub-branch of the time branch focuses on the recall of time facts such as provided in the illustrative example node, which enables conversion between time units. The sub-branch then extends further to compare and discuss time units, for example, (an) hour is longer than a minute. Further, a cross-link between the analog and digital nodes illustrates their interconnection when reading time to the minute such as shown by an analog clock and digital time of 7:15. The only other sub-branch from the digital node provides an example of the correct notation as 9:15. Overall, Stage Two introduces the concept of coordinated use of the hands of the clock to tell time, read and record time using digital and analog notations, convert between units of time, and read and interpret simple itineraries and calendars including an expanding repertoire of problem solving strategies.

Susan’s interpretations of Stage 3 syllabus outcomes are provided in Figure 4a. The main concepts are am/pm, 24 hour time, simplifying the problem, and time zones in Australia. The leftmost branch describes the distinction between two periods of the day as am/pm, which reads in Latin as ante meridiem or before midday and post meridiem or after midday, or alternatively labeled as 12 noon, midday or midnight. The meaning is not very clear with this last phrase of the proposition. According to the syllabus notes (not shown), midday and midnight need not be expressed in am or pm form; that is, 12 noon or 12 midday and 12 midnight should be used, even though 12:00 pm and 12:00 am are sometimes seen. A cross-link between the am/pm and 24 hour time nodes indicates that they can be converted to either form. Further, an integratively reconciliated connection to linking words (selects appropriate unit to), describes that events can be ordered based on time taken. The adjacent sub-branch (to the right under the 24 hour time node) describes its use to read and interpret real life timetables such as used to make simple travel itineraries; and to interpret, if they have scales, to decide a scale and drawing a timetable. The next sub-branch identifies where the 24 hour time is used. The final sub-branch provides an illustrative example, namely, 6 pm = 18:00. The concept map further illustrates that the MS3.5 outcomes (Figure 4b) include different strategies to determine time, such as simplifying the problem to determine the duration of events by using start and finish times to calculate elapsed time and that times can be measured and compared using a stopwatch. The next branch (to the right) describes time zones in Australia and daylight savings. Also time zones are defined as Eastern Standard Time (EST), which includes the listed four states Queensland (QLD), Victoria (VIC), New South Wales (NSW) and Tasmania (TAS). The adjacent sub-branch (to the right) indicates South Australia (SA) and Northern Territory (NT) are behind EST by a half-hour while Western Australia (WA) is behind two hours. Overall Stage Three outcomes focus on the use of the 24 hour time and am/pm notation and conversion between them and construction and interpretation of time lines using a scale.



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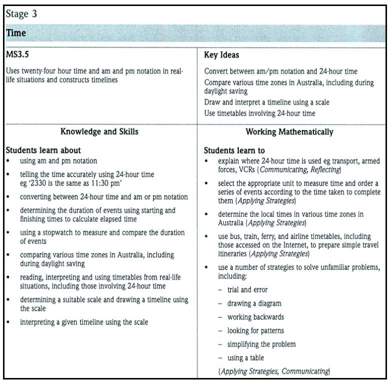


Stage 3

Time

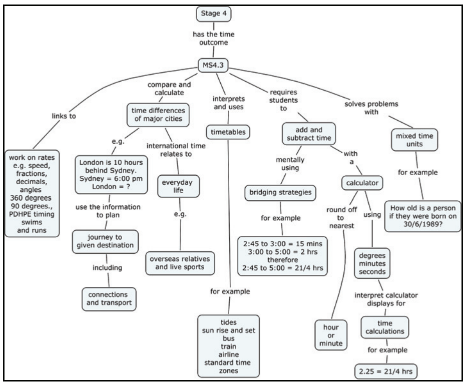
MS3.5	Key Ideas
Uses twenty-four hour time and am and pm notation in real-life situations and constructs timelines	Convert between am/pm notation and 24-hour time Compare various time zones in Australia, including during daylight saving Draw and interpret a timeline using a scale Use timetables involving 24-hour time

Knowledge and Skills	Working Mathematically
Students learn about • using am and pm notation • telling the time accurately using 24-hour time eg '2330 is the same as 11:30 pm' • converting between 24-hour time and am or pm notation • determining the duration of events using starting and finishing times to calculate elapsed time • using a stopwatch to measure and compare the duration of events • comparing various time zones in Australia, including during daylight saving • reading, interpreting and using timetables from real-life situations, including those involving 24-hour time • determining a suitable scale and drawing a timeline using the scale • interpreting a given timeline using the scale	**Students learn to** • explain where 24-hour time is used eg transport, armed forces, VCRs (*Communicating, Reflecting*) • select the appropriate unit to measure time and order a series of events according to the time taken to complete them (*Applying Strategies*) • determine the local times in various time zones in Australia (*Applying Strategies*) • use bus, train, ferry, and airline timetables, including those accessed on the Internet, to prepare simple travel itineraries (*Applying Strategies*) • use a number of strategies to solve unfamiliar problems, including: – trial and error – drawing a diagram – working backwards – looking for patterns – simplifying the problem – using a table (*Applying Strategies, Communicating*)

(b)

Figure 4. Concept map of the Stage Three Time syllabus outcomes.

The Stage Four concept map (Figure 5a) illustrates the link to work on rates such as speed, fractions, decimals, angles, degrees and PDHPE timing of swims and runs. PDHPE, Personal Development, Health and Physical Education, is one of the Key Learning Areas in New South Wales, Australian schools.



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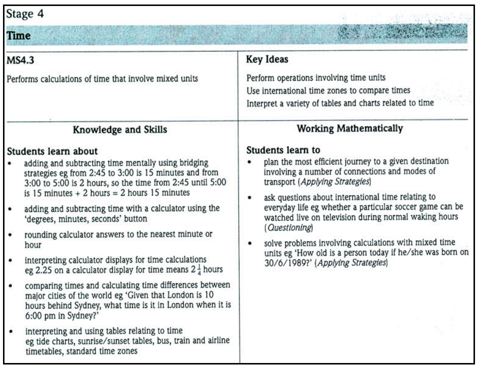


Stage 4

Time

MS4.3	Key Ideas
Performs calculations of time that involve mixed units	Perform operations involving time units Use international time zones to compare times Interpret a variety of tables and charts related to time

Knowledge and Skills	Working Mathematically
Students learn about • adding and subtracting time mentally using bridging strategies eg from 2:45 to 3:00 is 15 minutes and from 3:00 to 5:00 is 2 hours, so the time from 2:45 until 5:00 is 15 minutes + 2 hours = 2 hours 15 minutes • adding and subtracting time with a calculator using the 'degrees, minutes, seconds' button • rounding calculator answers to the nearest minute or hour • interpreting calculator displays for time calculations eg 2.25 on a calculator display for time means $2\frac{1}{4}$ hours • comparing times and calculating time differences between major cities of the world eg 'Given that London is 10 hours behind Sydney, what time is it in London when it is 6:00 pm in Sydney?' • interpreting and using tables relating to time eg tide charts, sunrise/sunset tables, bus, train and airline timetables, standard time zones	**Students learn to** • plan the most efficient journey to a given destination involving a number of connections and modes of transport (*Applying Strategies*) • ask questions about international time relating to everyday life eg whether a particular soccer game can be watched live on television during normal waking hours (*Questioning*) • solve problems involving calculations with mixed time units eg 'How old is a person today if he/she was born on 30/6/1989?' (*Applying Strategies*)

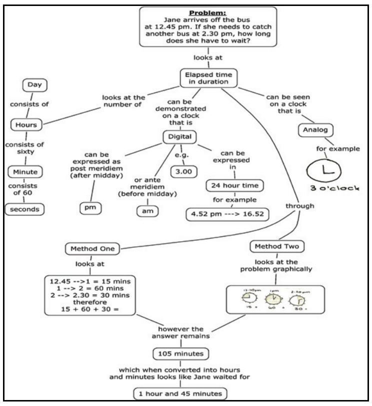
(b)

Figure 5. Concept map of the Stage Three Time syllabus outcomes.

Also the focus is on comparing and calculating time differences of major cities such as the problem posed as an illustrative example. The proposition extends to indicate that such information can be used to plan journeys to given destination including connections and transport. Time differences of major cities, that is, international time relate to every day life; for example, (for contacting) overseas relatives and (determining times for) live sports. The map further illustrates that MS4.3 involves the interpretation and use of timetables such as tides, sun rise and set, bus, train, airline, and standard time zones. The next branch involves the addition and subtraction of time using mental bridging strategies such as illustrated for the time elapsed between 2:45 to 5:00, and, calculator where answers may be rounded off to the nearest hour or minute. The right sub-branch of the calculator node describes that degrees, minutes and seconds may be used to interpret calculator displays for time calculations, for example, 2.25 = 21/4 hrs. Overall, Stage Four focuses on the performance of operations involving time units, use of international time and time zones to compare times, and the interpretation of a variety of tables and charts related to time.

4 Mathematics Problem Vee Diagram and Concept Map

Provided in this section are Susan's conceptual analyses of a mathematics problem using both a concept map and a vee diagram. The analysis is in terms of the prior knowledge and mains concepts required to solve the problem and the methodological aspects such as the given information, methods of solving the problem and answer to the focus questions. The results are displayed on a vee diagram (see Figure 6b). Also provided is a concept map of the problem (Figure 6a), illustrating the main concepts Susan expected students to understand and apply in determining the elapsed time as well as an overview of two methods of solving the problem. The given problem statement is positioned at the tip of the vee diagram (under *Problem*) with a focus question (If it is 12:45 pm, how long is it to 2:30 pm?) which Susan crafted based on her interpretation of the problem and what is needed to be obtained. On the left side of the vee (under *What do I know already?*) is a list of principles Susan anticipated a student would require in determining possible solutions. On the right side (under *How do I find my answers?*) are two methods of solving the problem. As well as providing the main steps, Susan also cross-referenced the appropriate principles (from the left side of the vee) as mathematical justifications for the steps on the right side. For example, principle 1 (P1: An hour is made up of 60 minutes) is used to justify the step: 1 → 2 = 60 mins (Line 2) of Method 1 (M1) while principle 5 (P5: Digital time can be directly converted from analog) is used to justify the steps: 2 → 2:30 = 30 min (Line 3), and 15 + 60 + 30 = 105 mins (Line 4, M1). In comparison, for Method 2 (M2), principle 4 (P4: Analog clocks have hands that indicate hour and minute and each number represents two times) is used to justify the times shown on the 3 analog clocks (Line 1), and 15, 60 and 30 minutes = 105 mins (Line 2) whilst principle 1 (P1) is used to justify the conversion from 105 mins to 1 hr 45 mins (Line 3). These principles appear directly on the opposite side (to the methods) thus reinforcing the close correspondence between the principles (propositions) and their application as justifications for the steps in the two methods.



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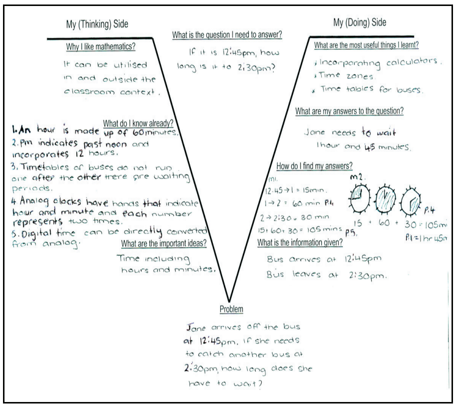

(b)

Figure 6. Concept map and vee diagram of a mathematics problem.

Also provided in Figure 6b, is an answer to the focus question posed, namely, Janes needs to wait 1 hour and 45 minutes (under *What are my answers to the question?*). Listed under *What are the most useful things I learnt?* at the top right side of the vee, are Susan's planned sub-topics for subsequent learning. Specifically, the use of calculators as flagged in Figure 5a (at Stage Four) while time zones were first introduced in Stage Three (Figure 4a). With the third sub-topic, simple timetables were initially introduced in Stage Two (Figure 3a), extended upon in Stage 3 (Figure 4a) before progressing to more complex timetables in Stage Four (Figure 5a). This simple to complex progressive trend is visible by tracing the occurrence of the timetable concept in the concept maps from Figures 3a through Figure 4a to Figure 5a. This section of the vee reflects Susan's future pedagogical intentions to extend the knowledge and understanding students gained by solving the problem. On the left side of the vee (under *Why I like mathematics?*), are Susan's expectations of what students would inevitably find for themselves as a result of engaging with such problems. Whilst only one vee diagram is presented here to illustrate its application in problem solving, many more were constructed to highlight the recursive application of different combinations of propositions from the five concept maps on time as justifications of multiple solutions to a problem. However, space constraints do not allow them all to be presented.

5 Journal of Reflections

The impact of constructing maps/diagrams on Susan's mathematical thinking, reasoning and pedagogical planning was documented in her journal of reflections during the semester (excerpts are in italics). Her main reason for taking the unit was to help her develop a better understanding of the mathematics syllabus and of the teaching of its concepts to primary students. Rather than the year twelve (end of secondary level) style that she "*was used to, of formulas are everything*", she perceived the need to approach primary mathematics from a primary perspective. In so doing, she felt she "*was taking a major risk in that (she) was approaching something that would take apart all (her) previously attained ideas and approaches*." Prior to the study, Susan viewed problems as simply questions to be answered and topics as containing a lot of information around one idea that needed to be taught to students. However, upon completing concept mapping and vee diagramming activities, it became increasingly clear that "*there was more to a problem than a formula and an answer*." Instead, "*problems consisted of a wide variety of factors that contributed to the understanding and subsequent answer*" such as the kinds of prior knowledge one possessed, which influenced the methods, and through reflection, the value of the learning experience, subsequent learning or extensions to the current activity. Consequential to constructing and completing more vee diagrams (similar to the example vee diagram provided), Susan realised that solving a problem became more than just "*an answer finder*". Initially, she found it difficult to complete the thinking side because "*(she) did not know how (she) constructed the answer on the right hand side …and thus, did not know what principles (she) had to list nor the important ideas*". However, she wrote, *"I struggled with this as, as a student I had only been taught the formulas never what was behind them*." With this self-realisation, Susan chose to challenge herself, namely, "*before finding the answer in future diagrams, first, (she) would look only at the question and think what (she needed) to know about it before (she actually solved) the problem*." Susan further admitted it was always difficult for her to explain problems to others, "*I always had difficulty in explaining what I wanted them to do and it frustrated me that they did not understand when I explained it the first time*." Through her reflections though, she said that her "*communication skills verbally (had) been assisted greatly by (her) written communication in both concept maps and vee diagrams*." She claimed, "*I now have the basic skills written before me and because it was me that had to construct the written version I was able to explain what I did verbally better than I had done before*." Consequently, through concept mapping syllabus outcomes, Susan eventually realised that a topic has a number of key and relevant concepts and recommended strategies that should be incrementally introduced, consolidated and extended for students through a suitable selection of learning activities to ensure the development of a conceptual understanding of the topic.

6 Discussion & Implications

Findings suggested Susan became competent and confident in her critical abilities to analyse syllabus outcomes and a problem and to display the results appropriately on concept maps and a vee diagram respectively. Critically analysing the list of syllabus outcomes at each stage for key concepts, working mathematically strategies and illustrative examples, she positioned the results in a hierarchy of interconnecting network of propositions. The resulting 5 concept maps collectively explicated visually and through propositions, a developmental trend for the teaching of key concepts and strategies. Initially introduced as single concepts, the main ideas became increasingly more complex and interconnecting with other ideas progressively through the stages. For example, the idea of telling time was introduced by reading the hour on digital and analog clocks in early stage one, consolidated again in stage one and extended to include the half hour. The descriptive language used also expanded from o'clock to include half-past. By stage two, telling time expanded to reading time to the minute to include 15 minute intervals with the introduction of the 24 hour and am/pm notation in stage three with the descriptive language expanding to quarter to and quarter past. Increasingly it became clear that mapping the syllabus outcomes (compared to reading from a sequential list as provided in the syllabus) has its advantages. For example, it facilitated a big picture view of key ideas and recommended strategies and reinforced the recursive but increasingly expanded nature of key ideas with each stage, which would enable a teacher to quickly identify potential pedagogical points of insertion for further developmental work be it introductory, consolidation, remediation or extension for meaningful learning. Through her maps/diagram, Susan communicated effectively with her audience. Because she had individually constructed them and actively engaged with the critical processes of analyzing and making connections, she was in a better and stronger position to explain and justify her ideas publicly. Susan further realised she was able to "*see the connections that infiltrated the topic*", consequently gaining a better understanding of sequencing learning activities. For example, "*(she) now understands what needs to be taught first and where (she) needs to go from there*" through the connections she made visible on maps and planned for on a vee diagram. Further, over time, completing the thinking side of a vee diagram eventually became much easier and done as efficiently as she did the doing side. At times, she challenged herself using the thinking side first to guide the development of methods, which was something she did not use to do before. This was a significant development in her critical approach to problem solving. For example, she recorded that the principles guided her development of appropriate solutions, and sometimes, if the method is done first, she could flexibly use the solutions to infer what the principles should be.

The presented data focused on time syllabus outcomes and formed part of Susan's work on the measurement strand over the semester. The maps/diagram explicitly illustrated the richness of information that can be captured by the combined usage of maps and a diagram in analysing syllabus outcomes for the former and making explicit relevant propositions guiding multiple solutions of a problem with the latter. Susan's maps/diagram demonstrated that a deep understanding of the time sub-strand was developed and reinforced through their construction. The vee diagram structure provided not only the space to express one's mathematical beliefs and critical reflections, but also projections for future learning. Overall, constructing maps/diagram evidently encouraged Susan to move beyond a procedural view to a more conceptually based justification of methods and a purposeful and clearer understanding of sequencing prior, new and future learning to promote students' developmental and conceptual understanding. Susan also became increasingly confident in her abilities and skills to use her concept maps critically as a means of identifying subsequent learning and the next developmentally appropriate method of solution guided by the networks of propositions. Finally, Susan concluded that constructing maps/diagram had begun "*a new chapter in (her) understanding and teaching of mathematics.*" She felt confident and her understanding of the sub-strand had deepened particularly in "*how each and every one of (the concepts and strategies) builds upon the prior knowledge of the last*". Findings from this case study contribute empirical data to support the use of maps/diagram to develop primary teachers' deep understanding of syllabus outcomes and the pedagogical use of concept maps to make explicit the developmental trends of key ideas across multiple stages and a vee diagram to highlight the critical synthesis of conceptual and methodological knowledge in problem solving and the importance of explaining, justifying and validating multiple solutions mathematically in terms of stage-appropriate propositions. The visual displays of networks of propositions on concept maps and theoretical and procedural information of a problem on a vee diagram effectively encapsulated the interconnection between the Knowledge & Skills and Working Mathematically Syllabus Outcomes. As the data demonstrates, constructing concept maps engenders a deep understanding of how concepts and recommended working mathematically strategies are developmentally progressed, consolidated and extended across the stages while constructing a vee diagram enhances the critical synthesis of the relevant mathematical principles and methods of generating solutions to a problem. Collectively the impact engenders a better pedagogical appreciation of how the main concepts and recommended strategies are developmentally progressed within each stage, and how its mathematical principles are applied in methods. These findings imply that concept mapping is a potentially useful strategy for unpacking the mathematics underpinning syllabus outcomes and making explicit developmental trends to facilitate pedagogical planning for teaching and designing learning activities while completing a vee diagram is a viable strategy for challenging students' critical thinking, reasoning and synthesis as they determine multiple solutions to a problem. The applications of these tools in the classroom as teaching tools for the teacher and consequently, the impact of this preparatory work on student learning are areas worthy of further investigation.

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CONCEPT MAPPING AND EARLY LITERACY: A PROMISING CROSSROADS

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Abstract. Through a qualitative analysis of conversation in teacher-guided concept mapping activities in a single kindergarten classroom over eight weeks, the present study explores the ways in which concept mapping promotes three important dimensions of emergent literacy. Specifically, teacher-child conversations facilitated the following three understandings important for literacy development: 1) Expository language genres can be used to obtain or provide decontextualized information; 2) A relationship exists between the elements of printed or symbolic representation and words in a spoken proposition; 3) Creating text is an inherently social process, with the purposes of communicating and sharing one's thinking with others. Findings illustrate, through excerpts of conversations, the various ways that these aspects of literacy were co-constructed between classroom participants, highlighting the important role of the teacher in scaffolding children's understanding of the meaning and functions of the concept map and its elements.

1 Introduction

In recent years, literacy has been understood as a process, beginning at birth, in which learners interact with text or other symbolic representational forms for the purpose of constructing meaning (Schreiber, 2005). Researchers interested in developmental aspects of meaningful text interactions have identified several aspects of *emergent literacy*, defined as strategies, attitudes, skills, and behaviors practiced by young children that contribute to "conventional" reading and writing proficiency, including: knowledge of alphabet system and letter-sound relationships, awareness of print in the environment, understanding print directionality, and understanding that print carries meaning (Goodman, 1986). As these constructs are intimately integrated to one another and to the context in which meaning-making takes place, learning environments for literacy development should support a broad range of knowledge and skills through demonstrations, social interactions, and models (NAEYC & IRA, 1998).

The present study explores the extent to which concept mapping may be used as an instructional tool in the early childhood classroom in order to facilitate several components of emergent literacy. Thus far, concept mapping has had limited use in early childhood classrooms, primarily centered on teaching conceptual structures (e.g., Figuerido, Lopez, Firmino & de Sousa, 2004; Gallenstein, 2003) or facilitating metacognitive control processes such as planning, monitoring and evaluation (e.g., Cassata & French, 2006). The potential for concept maps to facilitate a wider range of literacy activities in young children is far-reaching. The visual, hands-on, and representational qualities of concept maps provide a unique opportunity for children who are not yet readers to create, manipulate, share, and interact with text in a highly personal, meaningful fashion. In addition, the inherent structure of concept maps as logical propositions allows children to become familiar with expository, information-bearing language structures important for later school success.

1.1 Understanding Decontextualized/Expository Text Genres

Starting in the early elementary years, children are expected to become adept at "reading to learn" through providing and obtaining information using expository text, a distinct language genre associated with the use of specialized grammar and sentence structure while talking about a single, focused topic (Schleppegrell, 2004). In contrast to language often used in personal narrative, expository text is typically "decontextualized," with the primary purpose of conveying novel information to audiences with limited background knowledge (Whitehurst & Lonigan, 1998). As school and workplace success depends on the ability to comprehend informational texts, children need sufficient access to and opportunities to use expository language.

The nature and structure of concept maps provide ideal starting points for children to become familiar with the expository genre. Concept maps are representations of knowledge created when two or more concepts are connected by a linking word that designates their relationship, forming a *proposition* (Novak & Gowin, 1984). In contrast to narrative language often found in fictional stories, the structure of a proposition represented in a concept map (noun-linking verb-noun) follows a grammar based on formal, logical, and decontextualized meanings of objects and events. Concept maps commonly employ classification statements, and use generic, "timeless" nouns about *kinds* of things rather than particular instances or episodes (e.g., dogs, chairs, living things, trees). Linking words are in the present verb tense (e.g., dogs have four legs, trees are living things), and specify "relational" and "existential" relationships (e.g., is, has). Finally, as in expository texts, concept maps organize information in a "logical" structure, such as arranging information according to part-whole relationships, classification taxonomies, and causal relationships.

1.2 Linking Spoken Language to Symbolic Referents

In addition to their usefulness as conduits of decontextualized information, concept maps, in their basic propositional form, are also ideal for demonstrating relationships between spoken and symbolic language. The ability to divide a stream to speech into its component word units is difficult for most children entering school. An important developmental pre-literacy skill, "concept of word in text," involves an awareness of word boundaries important for developing literacy skills such as spelling and phonemic awareness (Flanigan, 2006).

Concept maps provide a concrete referent of a spoken proposition by graphically parsing the phrase into its component parts (concept-linking word-concept). In particular, concept maps draw attention to the existence of the "linking word" as a distinct entity carrying meaning. Modifications for young children, such as the use of picture-word cards to represent concepts, make propositional elements manipulable, increasing salience of word boundaries. Flanigan (2006) proposes that adults may facilitate "concept of word" by deliberately matching spoken word to printed word thorough reading, speaking and pointing to each word in a sentence. A more complex instructional strategy involves "mixing up" words in a sentence and asking children to place the words back together, a task requiring the child to check their work carefully upon completion. Concept mapping enables these recommended instructional strategies to be carried out within a single activity.

1.3 Understanding the Communicative Purposes of Text

A third important component of literacy involves the growing awareness that text is a product of communication, serving authentic purposes for sharing one's thinking with others as well as learning what others are thinking. Creating any literary product with this awareness becomes a challenging task involving regulation of the text's content, structure, and comprehensibility for the reader (Cox, 1994). Managing these elements of composition involves the strategic deployment of cognitive resources through planning, monitoring, checking, evaluating, and revising activities (Cox, 1994). It is important, then, for children to have opportunities to engage in tasks that foster children's planful and strategic control of textual meaning.

The completed concept map may be considered a literary product in which spoken text is represented in using written, pictorial, and physical referents. The salient visual and tactile qualities of each concept map element provide a means for children who are not yet proficient readers and writers to represent, preserve, and examine their own communicative activities. From planning of the map content, to monitoring of the finished product (through reading the final product, error detection, and checking for sense-making), to sharing their products with others, children develop an expectation that concept maps carry meaning and intent to communicate. In planning and monitoring concept maps for sense-making, young children also engage in perspective-taking both in making their own thoughts explicit for an audience, and in understanding that concept maps can represent what others are thinking.

2 Concept Mapping as Socially-Mediated Experience

A great amount of adult guidance is necessary in order for very young children to effectively engage in a concept mapping activity. Teachers must explicitly address with children the representational meaning of the concept map by explicitly stating the goals of the activity, such as explaining that concept maps "show what you know about something." In selecting concepts to add to the map, the adult must make explicit the intention to "make sense" of one or more concepts (McAleese, 1998), rather than viewing the map as simply "looking at the pictures" (Figuerido et al., 2004). As children learn specific meaning and purposes associated with concept maps through interacting with others who provide language, guided experience, and assistance to instill these tools with meaning, the concept mapping task is socially constructed. In the present study, qualitative methodology was employed to describe ways that, during an eight-week concept mapping intervention in a kindergarten classroom, adult-child communication during concept mapping instruction structured children's ability to understand and use the concept map for literacy-related purposes.

3 Methodology

3.1 Participants

Participating children (N=14, 7 males and 7 females) attended kindergarten in an urban city in the Northeastern United States. Children were of mixed ethnicity (5 African-American, 5 Puerto Rican, 3 Biracial, 1 White) and low socioeconomic status. The classroom teacher, Lynn, was a 26-year-old white female with 3 years of teaching experience (all names used are pseudonyms). Prior to beginning the study, the researcher met with Lynn for a three-hour training session to introduce concept mapping theory, materials, and classroom applications. The researcher provided additional support through planned meetings during the study.

3.2 Materials

Concepts were represented using photo-word cards with magnetic backing, and directionality was provided by magnetic arrows. Linking words were represented using voice recorders with magnetic backing, into which children were able to write their ideas on blank space provided on the front of each recorder. The use of voice recorders has been proposed as a technique to help pre-readers preserve the meaning of linking words and communicate the conceptual relationships to one another (Gomez, 2006). Concept maps were constructed and displayed on magnetic boards. Conceptual content knowledge corresponded to vocabulary and concepts from three life-science units from the ScienceStart! Curriulum, a hands-on, science content-based early childhood curriculum designed to foster language and literacy (French, 2004). The classroom teacher was previously trained to use the curriculum and had been implementing it for 2 years. The units corresponding to concept mapping lessons included 1) Types and characteristics of living things, and what things they need in order to grow; 2) Types and characteristics of healthy foods, the four food groups, and the food pyramid; and 3) Parts of a plant, and things plants need to grow.

3.3 Procedure

Children were introduced to concept mapping in three phases of increasing complexity over the course of eight weeks, learning to make maps using 2, 3, and 5 concepts (see Figure 1). At each level of complexity, children were provided multiple opportunities to practice concept mapping with varying levels of adult support (whole class large group, small groups of teacher and 3-4 children, and 1-on-1 teacher-child interactions). Each of the three adult-supported conditions were videotaped three times over eight weeks. Field notes provided narrative records of each observation session. Observational data were supplemented by child and teacher interviews throughout the eight-week period to check for children's task understanding as well as teacher impressions and informal observations.

Qualitative analysis explored how children's understanding of the structure and purposes associated with concept mapping developed in instructional interactions. Videotaped teacher-guided lessons (transcribed verbatim) were coded into categories according to the constant comparative method (Glaser & Strauss, 1967), using NVivo7 software, revealing ways that the genre, structure, and communicative purposes of concept maps were co-constructed in classroom interactions.

4 Results

4.1 Concept Mapping Scaffolds Expository Language

In all three instructional arrangements, children had multiple opportunities to generate and create concept maps in the expository genre. Beginning in the large group setting on the first day of the study, Lynn began to model spoken propositions in the "noun-linking verb-noun" format during group discussions, as well as ask questions prompting children to generate their own propositions: "Who can tell me something that is living?" "What did we say yesterday all living things need?" As children volunteered their ideas, Lynn revoiced children's comments (underlined): "spiders are living; people are living; all living things need water; all living things need food." Children began to contribute their own propositions in similar format. Lynn followed the general discussion by modeling propositions children had generated into concept maps. Finally, individual children had the opportunity to come to the front of the class to create a concept map to represent their spoken sentences, and read one another's concept maps.

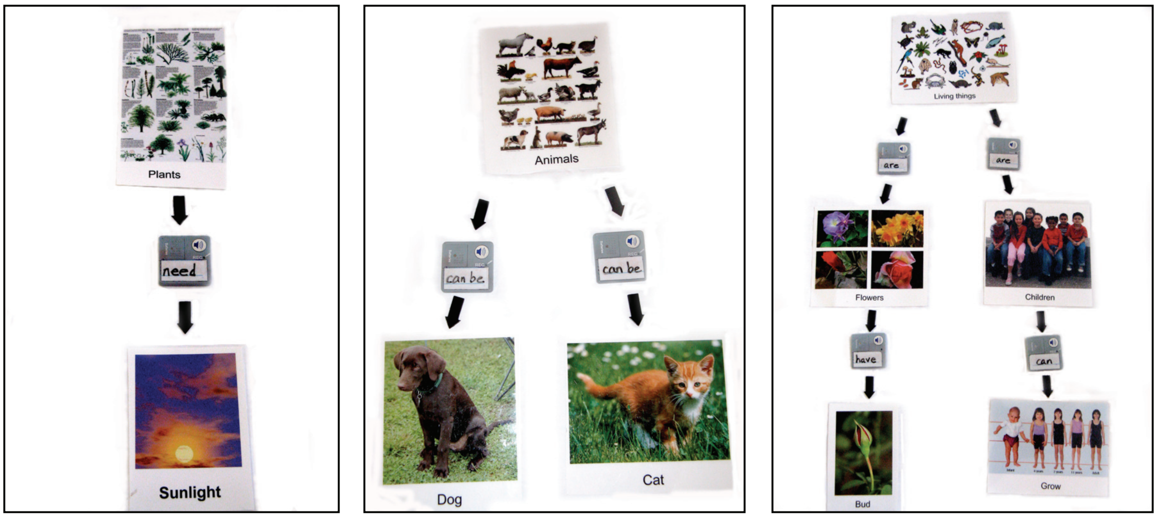

Figure 1. Examples of (a) 2-concept map, taught Weeks 1-2 (PHASE 1); (b) 3-concept map, taught Weeks 3-5 (PHASE 2), and (c) 5-concept map, taught weeks 6-8 (PHASE 3)

In the one-on-one and small group settings, Lynn supported the structure and language of children's stated propositions in a number of ways (see Table 1), by helping them think about defining attributes, category membership, and types of relationships that could be expressed with present-tense, "timeless" verbs. With this assistance, children were able to generate a large variety of different propositions, using the sets of concept cards in multiple combinations to construct meaning. As each unit built on the next, the set of concepts children were able to use increased, allowing a single concept to be discussed from many perspectives.

Defining Attributes	Category Membership	Logical Relationships
- What's one thing living things need? - Who can tell me something that is living? - What else is the same about living things? - How do you know a box is not alive? - What kind of living things need sunlight?...Do plants need sunlight, or do animals need sunlight?	- Is turkey meat? - Where would you put broccoli? Why don't you bring it up here and sort it for me? - Are trees animals? Are trees plants? - Can we say something else about the chicken? What group is it in? - Are plants living or non-living? - Is corn healthy or unhealthy?	- What do you wanna say about stems? Something that they, are part or, something they need? - Can you find a concept here, figure a way we can link it with water, so that it makes sense? - Think of something we can say about healthy foods, something they help, or something that…they do?

Table 1. Examples of decontextualized talk scaffolded by the classroom teacher

Small group interactions in particular revealed ways that expository sentences were co-constructed during the concept mapping activity. As Lynn encouraged children to make decisions together rather than individually, children used decontextualized language to talk to one another about concepts and their attributes. Lynn assisted children when necessary in negotiating the steps of the concept mapping task, explaining their decisions, guiding their behavior towards the goal of construction and checking the concept map for sense-making. Children in some small groups began to negotiate these regulatory tasks with one another with minimal teacher guidance. Two children, Alex and Tony, entered a period of rapidly "discovering" new propositions, showing a sense of excitement that increased as the map was constructed and they represented their thinking in the concept map:

Tony:	*(says to Alex)* Gimme those green beans.
Alex:	Green beans. Peas! *(hands "peas" to Tony)*
Tony:	*(puts "peas" at the top of the board)* Peas are –
Alex:	Vegetables.
Tony:	Yeah *(puts "vegetables" at the bottom left)*
Both:	Peas are vegetables
Tony:	Peas are, unhealthy food –
Alex:	Unheal – healthy!
Tony:	Oh! I got – I got one! Um peas are vegetables *(points to "vegetables")*
Alex:	*(puts "healthy foods" at bottom right)*
Tony:	Peas are healthy *(points to "healthy foods")*
T:	Those both make sense?
Both:	YEAH!
T:	Let's record em, let Tanya help write
Alex:	Marker! Marker!
Tony:	Write are, Tanya!
Alex:	Write are!

Although all the children in the classroom did not reach this level of group negotiation, the above excerpt illustrates the potential for concept maps to stimulate decontextualized thinking and peer-peer talk in a highly motivating context. The above examples demonstrate that young children are capable of using expository language forms to provide and share decontextualized information, and that through concept mapping, this genre can be taught explicitly using hands-on materials, teacher guidance and repeated opportunities for practice.

4.2 Scaffolding "Concept of Word" Using Concept Maps

In the one-on-one setting, Lynn spent a great deal of time helping children relate concept mapping elements to the parts of a spoken sentence. The language Lynn used when referring to materials reflected that each component (concept card or voice recorder) represents a "word," and each propositional arrangement of materials (topic concept card) – | linking word/recorder | – (related concept card) represents a "sentence." In explaining task instructions, Lynn reminded each child that they would be "making sentences." Lynn would frequently ask children, in helping them plan the content of their concept maps, "What's your sentence you're thinking of?" Lynn also related the materials to words by referring to their placement on the board and placement relative to one another in the concept map (see Table 2):

Abstract structure	Spoken word	Concept Map element	Placement
First word in sentence (subject)	"babies"	concept card	top
Linking word	"need"	voice recorder	middle
Related word (object)	"food"	concept card	bottom

Table 2. Correspondence between spoken word and concept map element, scaffolded by teacher

When checking the map for sense-making, Lynn stated that it was time to "play" or "read" the map (depending on whether the linking word was recorded or written), accompanied by running her hand over map, top to bottom, providing a nonverbal indication of where to start reading. Lynn modeled the reading of the concept map prior to asking the child to read the map, by pointing to each element as she stated each word from beginning to end. Allowing for a greater level of child participation, Lynn then pointed to each item (top-bottom) while the child said the corresponding word. Finally, when the child was ready to read the map on his or her own, Lynn pointed to first word of the proposition to direct a child's attention to where to start reading, giving the verbal instruction, "We'll read it all the way from the top, all the way down to the bottom," and the child was able to read the concept map as modeled by Lynn.

At times, children had difficulty understanding the one-to-one correspondence between word and symbolic element in the concept map, which was observed most frequently in concept map construction. A common "error" observed involved children recording the entire proposition into the recorder, instead of just the linking word or phrase. The process whereby Lynn worked with children to resolve this misunderstanding was frequently observed in one-on-one teacher-child talk, as illustrated in the conversation below:

T:	*(points to "baby")* Babies, *(points to recorder)*
Damian:	Need
T:	*(points to "food")*
Damian:	Food
T:	So what word are we gonna record here? *(points to recorder)*
Damian:	Need
T:	Good boy *(touches recorder)*
Damian:	*(speaks into recorder)* Babies, need –
T:	Alright now listen. Watch this *(touches "baby")* We have a picture of…
Damian:	Babies
T:	Now what – *(touches recorder)* So we have babies, *(touches "baby"),* and we're gonna do, NEED *(touches recorder)* so all you need to record is NEED

In this conversation, Lynn revealed an implicit understanding that each word is only represented once in the concept map, and while the concepts are represented by pictures, the linking words must be represented in the voice recorder. A similar but related understanding involved the knowledge that both the content and order of concept map elements must correspond the content and order of words in the spoken proposition. In the following example, the child chose an incorrect concept card ("orange") to correspond to the spoken concept ("food"). Lynn both modeled the one-to-one correspondence between spoken and symbolic element, and explained the necessity of matching spoken to represented concepts *in the order that they were stated*:

T:	So what do you wanna say?
Dejah:	Um. Children could – <u>can</u> eat food
T:	Alright well <u>listen</u>. We have a picture of what? *(points to "orange")*
Dejah:	Orange
T:	And we have a picture of…*(touches "children")*
Dejah:	Children
T:	Okay. If you're gonna say children eat food, then we need a picture of what?
Dejah:	Food
T:	Food. And what do we need to put at the top? Food, or children? What do we say first? Children eat food. So what goes at the top?
Dejah:	*(picks up "children" and shows it to Lynn)* Children

In the present study, children's ability to understand the correspondence between spoken and symbolic element was a determining factor in their success in creating concept maps that made sense and were interpretable to others. The fourteen children in the study displayed a wide range of individual differences in their "concept of word." Children struggling to understand the one-to-one correspondence between word and symbol required much greater teacher assistance, practice, and explicit instruction in creating their own concept maps. However, struggling children demonstrated qualitative improvements over time, requiring less teacher assistance and fewer hints during concept map construction at the end of the eight week period, suggesting that "concept of word" can be learned given appropriate resources and guidance.

4.3 Understanding the Communicative Functions of Concept Maps

Throughout the intervention, Lynn made salient the communicative function of concept maps in a number of ways. Lynn frequently followed a completed concept mapping task by a summative comment related to its "readability," such as, "Somebody can come and read what you wrote, right?" or, "Can somebody else read it?" Alternately, Lynn might read the map herself, pointing out possible sources of confusion for the reader if the map was missing information, for example: "Okay what are you missing here *(pointing to empty space where arrow should be)* cause I'm gonna read it, and I'm gonna get to here and then I'm not gonna know what to do. What am I missing?" Lynn further scaffolded the intentional nature of concept maps by inviting individual children to express their understandings of concept map elements as they relate to communicative purposes, for example: "What do we need a marker for?" or "What do arrows help us with?" In small and large groups, Lynn encouraged children to read one another's concept maps as a way of checking for sense-making. The following large group discussion illustrates ways that understanding the communicative function of the concept map was constructed as one child attempted to read another child's concept map:

T:	Luis, can you read her sentence if she hasn't written any words or recorded any words here?
Luis:	Children need food
T:	Now Luis think-
Tony:	Children <u>can eat</u> food
T:	Oh! Look at that. We have one saying it could say children <u>need</u> *(touches recorder)* food, and then Tony is saying, children *(touches "children")* <u>can eat</u> *(touches recorder)* food. If Renee doesn't record anything here, do we know what she's thinking?
Child:	No *(multiple voices)*
T:	No. She could be thinking either of those. Does children <u>need</u> food make sense?
Child:	Yes *(multiple voices)*
T:	Does…children <u>can eat</u> food make sense?
Child:	Yes! *(multiple voices)*
T:	Yes. Renee what were you thinking when you made this map?
Renee:	Um *(stands up)* I was thinking…I said…um…
T:	What did you want to say?
Renee:	I think I'm gonna…um…write the word
T:	You wanna write the word? You can write the word. *(gets dry erase pen)* What word are you gonna write?
Renee:	Need

The above discussion helped children understand that recording or writing the linking word is crucial to the "readability" of the concept map. The conversation required children to take Renee's perspective, as Lynn encouraged Renee to express her thinking aloud. Children were also required to take the perspective of the reader with a goal of finding out what Renee was thinking. Lynn emphasized two different children's interpretations of the map, highlighting that the intentions of the creator are unknown if the concept map has missing information. At the same time, Lynn encouraged Renee to plan her sentence by stating the linking word before recording it in the map. Lynn also encouraged monitoring by asking the group if the two propositions suggested made sense. These planning and monitoring activities were encouraged throughout the study, helping children consider the link between internal knowledge and final product, the completed concept map.

5 Discussion

The current study broadens the applicability of concept mapping for use with young children, highlighting the diverse ways in which creating and revising concept maps can contribute to children's developing literacy skills. Findings illustrate that concept mapping makes expository language explicit to young children through the creation and summative representation of logical propositions. Concept mapping allows for alternate interpretations of experience, including new ways of representing and organizing knowledge separate from the immediate context, and new linguistic forms to express and talk about concepts. Secondly, the physical, componential nature of concept mapping renders the task a natural tool for increasing children's awareness of individual words within sentences, as the concrete representation of each propositional element makes salient the relationship between spoken word and textual representation. Finally, concept mapping provides an opportunity for children who are not yet readers to plan, create, and check their own literary products. In this manner, concept mapping acts as a "precursor" to tasks of written expression. Representing knowledge in visual and auditory modalities allows content to be readily shared, and problems easily detectable, enabling children learn to both consider audience understanding, and to check the correspondence between the concept map and their own ideas.

Several structural parameters were built into the present study. To reduce task complexity, the children were not asked to draw, photograph, or label their own concept cards. The use of attractive color photographs with corresponding word label was motivating for children, and made most concepts easily identifiable for children who were pre-readers. Using this structure, the classroom was able to establish shared meaning of image to concept across all individuals, increasing ease of communication and reducing fine motor requirements of children with difficulty in this area. Likewise, children in the present study were instructed in how to make three specific map structures in order to reduce map complexity given time constraints. Reducing task complexity enabled children to devote more effort and mental capacity to engage in cognitive and metacognitive processes without becoming overwhelmed by other task demands.

A next research step may involve developing causal models between dimensions of emergent literacy facilitated by concept maps, and conventional measures of reading and writing, over time. However, developing an outcome-based study based on "measures" of literacy behaviors may have several limitations given that components of literacy are developed gradually, rather than "all-or-nothing," they work in interaction with one another rather than in isolation, and they are context-dependent. A more fruitful approach may examine, through observational methods, whether engagement in natural literacy practices changes in relation to classroom concept mapping activities. It will be important for future studies to expand research settings beyond those presented in the present study, to include a greater number of children, individuals from diverse ethnicities and backgrounds, and in different geographic regions. The intersection of concept mapping and early literacy development is ripe for investigation, as concept mapping potentially "bridges" young children's ability to engage in complex literacy practices, building familiarity with and motivation for activities involving meaningful textual representation.

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CONCEPT MAPPING AND MOVING FORWARD AS A COMMUNITY OF LEARNERS

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Abstract. This paper describes some examples of how a group of teachers came together as a community of learners to plan for the implementation of an innovative teaching and learning strategy. Concept mapping was the strategy and none of the teachers had prior experience in its classroom application. During a twelve-month project the teachers, who taught both primary and secondary students, completed professional development activities to become familiar with the technique. These included a variety of mapping tasks that enabled teachers to reflect on their practice and to share ideas before introducing the strategy as part of their teaching. A review of teachers' feedback indicated that the professional development activities undertaken provided quality support for the introduction of an innovative teaching and learning strategy.

1 Introduction

In the Australian teaching and learning context, professional teaching standards which describe the attributes of teachers at key career stages are becoming increasingly important as frameworks for informing beginning and experienced teachers who wish to develop their teaching practice or to plan for ongoing professional development (e.g., Teaching Australia, 2007). Professional associations have also developed standards that describe aspects of professional knowledge, professional practice, and professional attributes of excellent teachers in the respective disciplines. The mathematics and science standards (AAMT, 2007; ASTA, 2007), for example, refer to the way excellent teachers: (1) seek out effective strategies and techniques for teaching and learning; (2) engage in professional development that is collegial; (3) actively explore new teaching ideas; and (4) initiate purposeful dialogue with students about their subject.

This paper reports some data from an Australian Schools Innovation in Science, Technology and Mathematics (ASISTM) project in mathematics and science based on the introduction to concept mapping to primary and secondary teachers who had no previous experience in concept mapping. Relevant to the Project were a number of the ASISTM aims, namely:

1. to encourage innovation by (a) fostering a culture of innovation in schools; (b) improved levels of coordination of science/mathematics teaching and learning between primary and secondary schools; and (c) increased collaboration between schools and universities; and
2. to promote world class teaching and learning through (a) changes and improvements in teachers' approaches to, and techniques in, teaching science/mathematics; and (b) enhanced student interest and engagement in science/mathematics learning (ASISTM, 2007).

The Project introduced hierarchical concept maps to teachers and students as meta-cognitive tools, firstly, to foster critical inquiry and competence in analysing mathematics and science content embedded in problems and activities and, secondly, to address students' mathematical and scientific literacy needs. To ensure the sustainability of innovation, teachers were trained first with appropriate support over a term before classroom trials. For teachers to assimilate innovative approaches, an important aspect to consider is their preparedness to take part in reflective practice and to share emerging understandings with peers within a community of learners. Hence, this paper focuses on some of the outcomes of the processes intended to support the teachers as learners of innovative strategies, reflective practitioners in a community of learners, and as classroom implementers of innovation. The focus questions guiding this paper are:

1. What are some of the issues and concerns raised by teachers when introduced to an innovation, such as concept mapping?
2. What processes did teachers go through to resolve these issues?
3. In what ways did concept mapping provide a useful planning tool for teachers?

2 Professional Development

An important characteristic of a successful professional development program, as articulated by Loughran & Gunstone (1997), is *working with*, rather than *doing to*, *teachers* by considering two contextual influences. First, the difficulty of sustaining professional learning in schools due to the uncertainties of professional practice. Second, teachers need to constantly refine their approaches to ensure pedagogical practices are meaningfully applied and developed to support student learning. Clarke and Clarke (2007), recognising teachers' central role, proposed *ten key principles* to increase the likelihood of long-term and effective professional development and to identify the processes teachers engage with during associated programs. For example, addressing the principle of "issues of concern and interest, largely (but not exclusively) identified by the teachers themselves, and involve a degree of choice for participants" (Clarke & Clarke, 2007, p1) translates into negotiating the content and structure of professional development with teachers. Failure to place teachers as the central agents to reform practice or implement innovations, can only lead to disappointment in the achievement of positive outcomes (Van Driel, Beijaard & Verloop, 2001).

A four-point-scheme working-model for professional development, identified by Black and Wiliam (1998) with communities of learners who reflect on their practice for development, include (1) the provision of support for teachers to work together, (2) teachers incorporating ideas into classroom practice; (3) balancing the requirements of curriculum imperatives and meaningful learning; and (4) teachers receiving feedback from peer/external review of their practice. Overall, to guide development within the teaching profession, Crowther, Kaagan, Ferguson and Hann (2002) propose that teachers need to be supported to embrace learning, participation, collaboration, cooperation and activism.

3 Concept Mapping in Innovation

Ausubel's meaningful learning theory proposes that learners' cognitive structures are hierarchically organized with more general, superordinate concepts subsuming less general and more specific concepts by progressive differentiation and/or integrative reconciliation (Ausubel, 2000; Novak & Gowin, 1984). Through maps/diagrams, students illustrate publicly their interpretation and understanding of a topic/problem. Concept maps are hierarchical networks of interconnecting concepts (nodes) with linking words describing the nature of interconnections (Novak, 2002; Schmittau, 2004). Concept maps provide a metacognitive tool that can be used by teachers and students alike to organize and reflect on their knowledge (e.g., Conlon, 2004; Fellows, 1993; Fraser & Edwards, 1987; Novak, 1998; Novak & Cañas, 2008). Since the original work of Novak and Gowin (1984), methods for the analysis of concept maps have incorporated both quantitative and qualitative procedures. Each procedure provides different information about the quality of concept maps although each is directed towards obtaining a tangible representation of cognitive structure. Concept maps, together with the discussion that surrounds their preparation, provide an ideal reflective context for teachers as they interpret a new teaching and learning strategy, and plan for its implementation.

4 Methodology

A two-day professional development workshop (October 2005) introduced ten teachers, from two independent primary and central schools, to the innovative strategies of concept mapping and vee diagrams in mathematics and science. Presentations were interactive allowing teachers to field questions for clarifications of issues and ideas and to critique presented maps/diagrams. The emphasis was to illustrate the innovative ideas through examples of maps/diagrams previously constructed by secondary students and student-teachers to illustrate applications (a) in *learning* such as analysis of problems and activities including illustration and communication of one's understanding, and (b) in *planning* instruction such as teaching sequences, lesson plans and learning activities.

Small group activities invited the teachers to work cooperatively to co-construct concept maps by brainstorming ideas, compiling concept lists, organizing concepts into meaningful hierarchies, linking concepts, and including 'linking words' describing meanings of inter-connections. Teachers practised concept mapping techniques in activities related to syllabus outcomes, specific problems, structured activities, and textbook extracts. Group presentations and peer critiques followed each activity and these provided critical feedback to further improve the hierarchical organisation of concepts.

During the professional development sessions, participants reflectively considered how they might incorporate concept maps into future planning and classroom activities. Teachers also experimented with maps before meeting again in reflection sessions. The presented data includes exemplars of concept maps constructed during the workshop, negotiated during reflection sessions and constructed by primary students during classroom trials.

5 Results: Selected Concept Maps

The material presented is framed around the three different roles enacted by teachers during the Project, namely, teachers as learners of innovation, reflective practitioners in a community of learners, and classroom implementers of innovation. Material is drawn from teacher comments and samples of concept maps related to both mathematics and science topics.

5.1 Teachers as Learners of Innovation

After initial introductory sessions on the rationale and techniques for the preparation of concept maps, teachers worked in small groups on a number of tasks in three areas. The first was related to syllabus interpretation during which teachers interpreted the requirements of the syllabus and organised these requirements into a concept map. The second related to the conceptual knowledge required for a specific problem about comparing the area of a rectangle and a square. The third was about the conceptual knowledge for a specific topic during which teachers discussed collaboratively the essential concepts needed to introduce a teaching sequence about 'substances'. Each of these tasks is discussed briefly in terms of the potential benefits to the teachers as a community of learners.

5.1.1 Syllabus Interpretation

Figure 1 illustrates primary teachers' planning concept map about 'Number' for students in the middle years of primary schooling based on syllabus material.

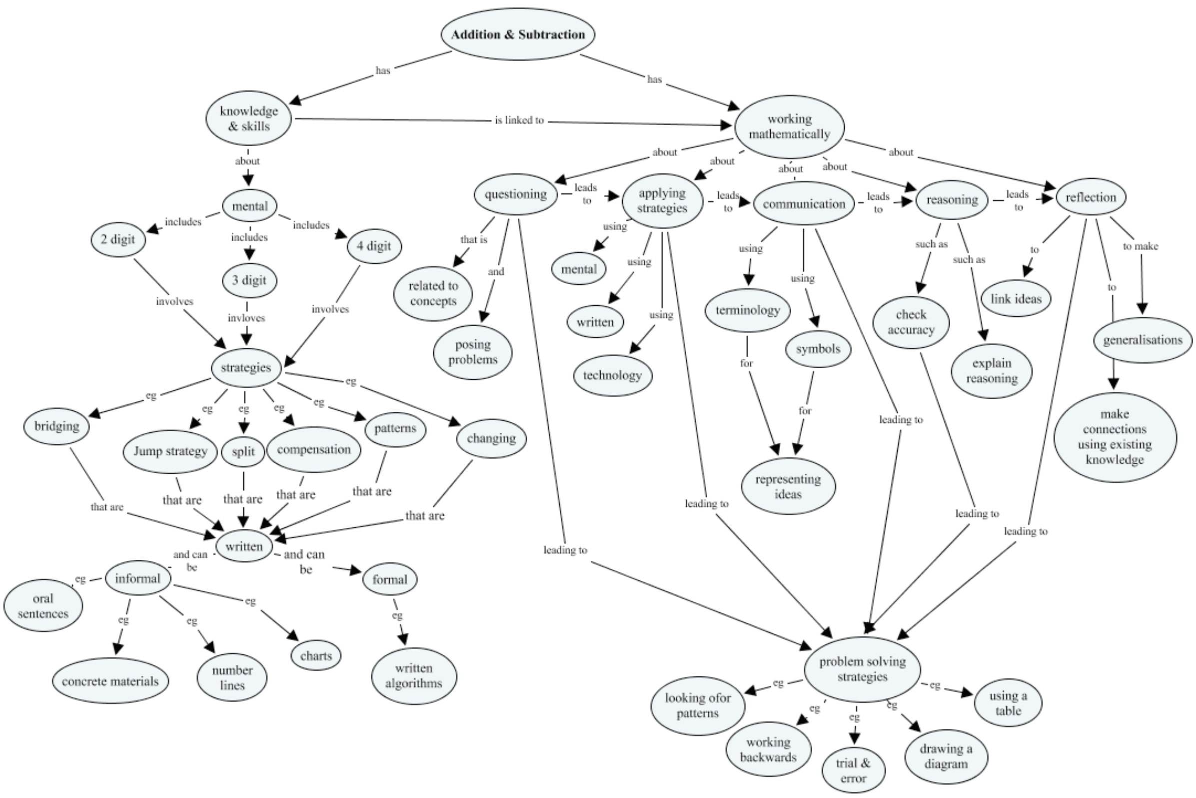

Figure 1 Concept Map for 'Number' Prepared Collaboratively by Teachers

The discussion which followed the presentation of this map highlighted two aspects of working as a community of learners: Firstly, the use of concept maps as an advance organiser provided a framework for discussion; and secondly, the discussion provided an opportunity for sharing ideas that reinforced good practice.

> *Presenter: We would begin with the two digit numbers and work our way through and build on that to the three and then the four. Once they've got the mental strategies in place we can then start to put it into the written from and written can be informal of formal. On the informal side, we looked at oral sentences where*

children explain what they are doing using concrete materials such as open number lines … but on the formal side we would look at the written algorithm… where we go from here you would have to do a concept map for two digits, then another for three …

Teacher: They make excellent scope and sequence statements.

Teacher: The structure … would be a series of lessons say over two weeks …

Teacher: You could photocopy a number of these and for each sequence of lessons highlight the relevant parts.

5.1.2 Specific Problems

Figure 2 provides an overview of teachers' beliefs about a specific problem related to area and perimeter. The problem provided data about the dimensions of a rectangle from which a comparison was required of its area with that of a square of identical perimeter.

Figure 2 Concept Map for and Area and Perimeter Problem Prepared Collaboratively by Teachers

The concept map illustrates progressive differentiation of the focus question into the language, knowledge and skills, working mathematically, and prior knowledge needed to complete the question. The second half of the map describes the process of obtaining an answer based on a synthesis of an understanding of rectangles and squares. Much of the discussion about this problem focused on how different year levels would approach it. The majority of comments focused on the section of the map related to prior knowledge about rectangles and squares, and language. Representative comments included:

You could get them to solve it in the lower stages (middle primary years) if you gave them a picture of the rectangle and of the square. They could then compare the areas.

A lot of kids in my Year 6 class couldn't actually read that … I have to be more visual for them.

My children will have trouble with the language … perimeter, area, greater – my kids just say 'bigger than'. As for 'figure', they would use the word 'shape.'

I'd have to scaffold that … because they could understand the question, but they would get completely lost as to where to start. They can't break it down.

I'd still use the same wording with my class but go through the whole thing and make sure they understood what area was, what a rectangle was, what perimeter was, what I meant by figure and by greater. So that would be the first part of the problem.

I had a very algebraic solution, but that is for Stage 4 or 5 (middle secondary years of schooling) … using formulae. It depends on the class. If I have a Year 7, then I have to use diagrams.

5.1.3 Specific Topics

Figure 3 details the relevant content that one group of teachers regarded as important when starting a topic about substances with students in the later years of primary schooling.

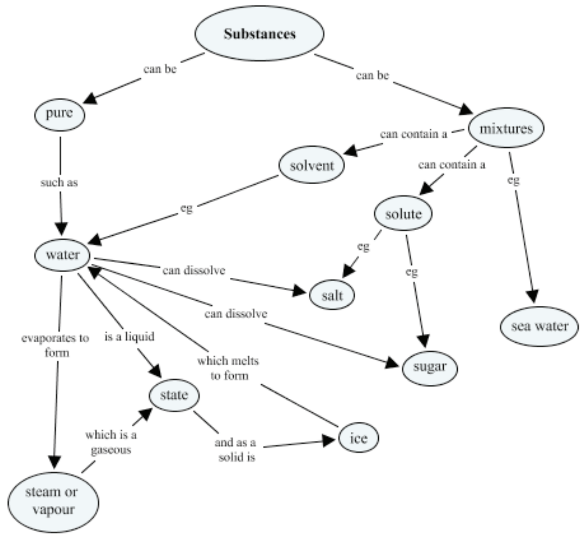

Figure 3 Concept Map for the Topic 'Substances' Prepared Collaboratively by Teachers

During discussions about this map as it was being prepared, the teachers had agreed that they wanted to focus on the essential difference(s) between pure substances and mixtures. They wanted to do this by selecting a substance with which students were familiar and which could be used in simple activities. The structure of the map reflects these priorities: the terms 'pure' and 'mixtures' placed at the top and, as they are differentiated, the term 'water' is given prominence through the use of cross-links.

5.2 Teachers as Reflective Practitioners

Two examples of reflective practice are provided here. The first relates to feedback teachers provided in a group setting when concept maps were discussed during presentations, i.e., peer critiquing. The second relates to how one teacher considered modifications to the planning of an activity as a way of engaging students as fully as possible. The first reflective example relates to the concept map in Figure 3 (Substances) prepared for students in the later primary years of schooling. Part of the discussion during the group presentation of this map included a justification of the uses of 'water', 'sugar' and 'salt' as exemplars for dissolving. This was continued in the discussion which followed.

Presenter: … we would use the example of water because that's familiar to everyone and water can dissolve sugar which is a solute or can dissolve salt which is another solute and salt with water is sea water and our activity would be to dissolve salt in water to demonstrate that dissolving action. And make a product they could relate to as well.

Teacher: I think you should remember the milo thing

Teachers: That's a good one, because they could drink it at the end.

Teacher: I like the jelly one … because salt water doesn't sound as attractive in comparison.

Presenter: We were trying to think of something with the sugar and the water … cordial would also have been a good one. But I like the jelly crystal idea …

Teacher: But it's a complex one.

Presenter: The trouble with the jelly crystal one though is it forms into a mixture but then it forms into a solid sort of thing.

Teacher: There are more factors there; it's not only the dissolving.

The second example of reflecting on practice related to how to contextualise a problem for students. One of the schools involved in the project had a predominantly aboriginal population. As part of using concept maps as a planning tool to introduce a lesson on measurement to upper primary students. The lesson activities were based on the use of road maps and the teacher had extracted the relevant syllabus knowledge and skills for the activity including drawing on prior knowledge of working mathematically. When presenting the overview of the activities to other teachers, the following comments were included:

… we're looking at abbreviations of kilometres and metres, and we will be recording lengths or distances using metres or kilometres that are included in the knowledge and skills. I would include aboriginal language and tribal boundaries, like for example it says how far from Tenterfield. I would say how far from Goombangui Country down to Bunjalung Country; and how far is it from Taree, which is in the Biripai area, to Kempsey, which is going back to Dunguddy Tribal land …

There are three key aspects to moving forward as a community of learners embedded in these two examples. Firstly peer critiquing provides an opportunity to discuss prepared maps in a non-threatening setting where teachers could share ideas and discuss how they might be included. Secondly, additional strategies for engaging students can be shared, e.g., the use of cultural contexts. Thirdly, examples that might present conceptual problems for students, such as dissolving leading to the formation of a solid, can be discussed fully.

5.3 Teachers as Classroom Implementers of Innovation

Throughout the project, teachers selected opportunities to introduce concept mapping as a stand-alone activity and as a component of preparing vee diagrams. These activities were carried out with classes in the primary and secondary years, and for both mathematics and science topics. The example provided in Figure 4 was prepared collaboratively by a group of three students in the middle primary years and offers some insights into the structure of their knowledge.

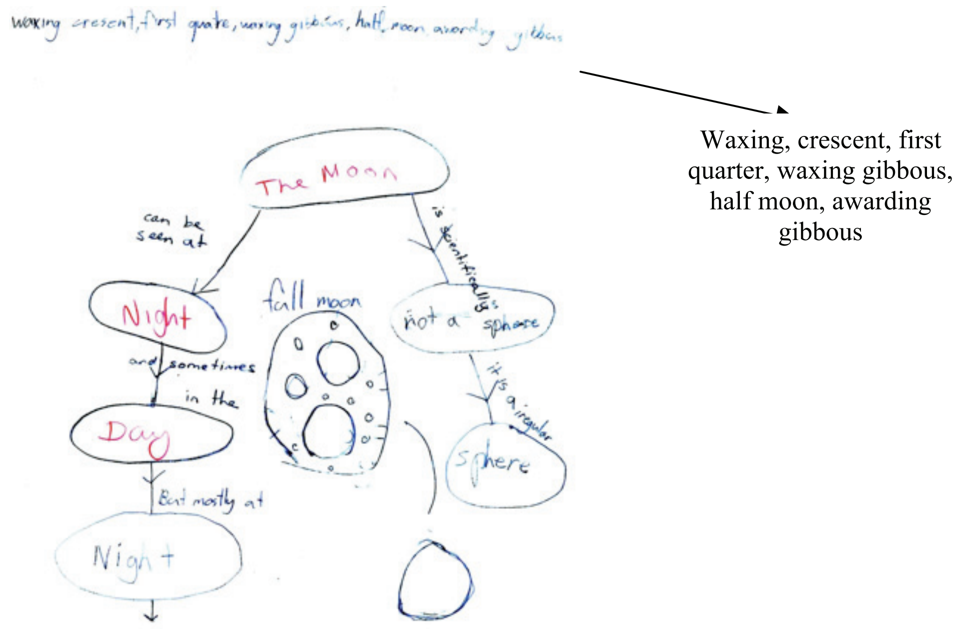

Figure 4 Concept Map of 'The Moon' Prepared Collaboratively by Year 3 Primary Students

The map and the discussions that took place during its preparation provide some important feedback for teaching and learning. Firstly, the fundamental unit for preparing a concept map, namely the proposition, has been successfully used by this group of students. Secondly, the students have written a number of concepts about the moon at the top of the map but have not incorporated them into the map. This absence suggests that students may be able to remember individual pieces of information about the moon, but they cannot yet apply them to this particular task. A further indication of the lack of consolidation of new information can be found in the use of the term 'awarding gibbous' which may be how 'waning gibbous' has been recalled. Thirdly, the students have incorporated a picture of the moon as they see it. These points suggest that, although concept mapping can be used successfully with this age group, the outcome of the activity provides some important feedback about the extent to which new terminology has been incorporated into students' existing knowledge structure.

Some representative comments from the students' conversation as they prepared this map further illustrate the separation (for students) of prior knowledge – or existing conceptual structure, new information, and the outcome of a learning task.

- *The moon is interestingly made of cheese ... it has different shapes.*
- *The moon comes out at night mostly ... and sometimes at daytime.*
- *We might not know the shape of the moon ... and there is a man in the moon.*
- *The moon has magma and nuclear.*
- *The moon moves ... and circles the moon for 24 hours.*

6 Summary of Findings

The project was guided by three key questions framed around how teachers would respond to an innovative teaching and learning strategy, how teachers might resolve identified issues, and how teachers would perceive the effectiveness of concept mapping as a planning tool. From the examples presented in this paper, some preliminary answers can be put forward. Firstly, teachers recognised the benefits of using concept maps and they created a non-threatening environment in which they openly discussed the learning of a new technique and were prepared to present their initial maps for peer discussion. They produced a number of detailed maps for different contexts and use them to resolve problems that they perceived students would experience. Concept maps were produced as an advance organiser for a syllabus topic (Number) that led to discussions about how student learning might be sequenced. Maps were also produced that outlined the conceptual structure for the introduction of a new topic (Substances). Teachers also used maps to identify the essential knowledge and skills that students would need to solve a particular problem in mathematics (perimeter and area problem).

Secondly, the extended discussions during presentations (peer critiquing) enabled teachers to share their knowledge, as well as add to and refine constructed maps. Through sustained conversations about subject matter and listening to each other's views about the important knowledge and skills that students need to acquire, teachers had the time to reflect and to gain a deeper understanding of their practice. Thirdly, teachers found concept maps a valuable way of documenting consensus amongst peers and for summarising the requirements of syllabus documents. Most importantly, in the context of a new strategy, collaboration, sharing knowledge and documentation were modelled by teachers in a way that provided them with the confidence to introduce concept mapping into their classes. Some comments taken from the teachers' reflection sessions qualify these points:

To make them (concept maps) relevant, you need to ensure that you begin them at the right level.

I'm beginning to see their applicability more when working collaboratively with teachers to keep them aware of language difficulties etc.

I feel that concept maps are a great tool for planning – for working out what the key concepts are and for knowing where you are wanting to head with the unit.

In addition, four characteristics of exemplary practice were identified in the professional standards for mathematics and science teachers. Teachers who took part in the study indicated that the professional development activities based around the implementation of concept maps supported those characteristics, thus providing an informed basis for further work in these areas, namely:

- As an effective strategy for teaching and learning: *Concept maps are a great way to organise your ideas;*

- For providing opportunities to engage in professional development that is collegial: *We realised the importance of collaborative work and that working as part of a team could give more satisfaction;*
- In finding ways to actively explore new teaching ideas: *It helps to be able to break the information to be taught into little pieces;* and
- For initiating purposeful dialogue with students about their subject: *Concept maps are helpful for students to organise their learning.*

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CONCEPT MAPPING AS A STRATEGY TO EXPLORE TEACHERS' MENTAL REPRESENTATIONS ABOUT THE UNIVERSE

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Abstract. Concept maps are especially useful tools to identify knowledge available in the subjects' cognitive structure and also to present the ideas, concepts, and propositions necessary for the construction of new meanings related to a specific scientific field, such as cosmology. The theories of mental models by Johnson-Laird and of conceptual fields by Gérard Vergnaud have been used as a framework for the development of this study. It presents findings of a qualitative analysis of concept maps used as pedagogical strategy to inquire about the mental representations, and their possible evolution, held by a sample of teachers, who participated in the activities offered by the Barranquilla Planetarium, in Colombia, in relation to models of the universe.

1 Introduction

This paper is part of a research project that aims at exploring and interpreting, within the framework of cognitive psychology representational theories and cosmological models developed throughout history, the internal representations of science teachers based on their external representations of the universe and on the elements they use to explain them (Larios, 2007).

It was developed in two stages: the first was an exploratory one to characterize the science teachers' mental representations about the universe; the second stage was experimental in which a methodological strategy was applied based on the converging points of the theories of mental models (Johnson-Laird, 1983) and of conceptual fields (Vergnaud, 1990; Moreira, 2002) to depict the evolution of mental representations and the knowledge those teachers had about scientifically accepted cosmological theories and models.

The underlying assumption that to promote meaningful learning one must master the scientific content to be taught (Moreira, 2006) guided the design and application of a methodology, during the experimental stage, that would help getting to know the degree of understanding about the universe and the conceptual mastery of the underlying theories, laws, and principles linked to the cosmological models of a sample of five teachers of social and natural sciences.

Among the instruments used in the research, concept maps have shown to have great potential in allowing for an approximation to the representations of the teachers as well as their possible evolution through conceptual enrichment favored in the pedagogical intervention (with the teachers involved in this study, in the planned activities for the sessions of the Planetarium, in Barranquilla). Research findings reported here correspond to the qualitative interpretative analysis of the concept maps produced by the teachers during the experimental stage of the research, and they might point out to the evolution of the initial models about the universe towards to other ones with a closer agreement to accepted scientific models.

2 Theoretical framework

Some elements of the theories of mental models by Johnson-Laird and of conceptual fields by Gérard Vergnaud are emphasized here as relevant to the aims of this paper. Coincidences or points of convergence, between the two theories are also pointed out since they were important to the planning of the methodological approach for the sessions with the teachers in the Planetarium, as well as in the interpretative analysis of the representations about the models of the universe suggested in the concept maps.

2.1 Johnson-Laird's mental models

Johnson-Laird's (1983) theoretical approach assumes that human beings do not apprehend the world directly, but they do so through the representations of the world they construct in their minds. Johnson-Laird believes that "*to understand a physical system or a natural phenomenon one needs to have a mental model of this system that will allow him/her—the person who will build it—to explain it and to predict about it*" (1983, p.430).

According to this theory, mental models are considered as structural analogues of state of things in the world and are instruments of understanding and inference. They have an internal structure, that is, they are made of *elements* and *relations*, and they are constructed from some basic elements, which the author calls them *conceptual primitives*, that are innate and are organized within a given structure. They might be basically propositional or imagistic or they might contain both propositions and images. Johnson-Laird still conceives the existence of what he calls innate *procedural primitives*.

Mental models, according to the author, should not have any elements without function and meaning (1983, p. 419), which indicates that, when facing a situation, elements that have been chosen to interpret it together with the conceived, or perceived, relations among them establish an internal representation that serves as a substitute for this situation. When internally manipulating these substitutes, some properties of the system, as well as inexplicit relations among their components, can be recognized or directly inferred (Moreira, 2005). In this regard, we believe the theory of mental models can offer support to the investigation of the construction processes and conceptual development of individuals. Thus, when we get to know what elements are involved in a mental representation about a particular event (in this paper about mental models) and, furthermore, what relations are established among them, we might infer the individuals' stage of conceptual development.

2.2 Gérard Vergnaud's conceptual fields

Vergnaud's theory (1990; Moreira, 2002), similarly to Johnson-Laird's theory (1983), complies with the idea that knowledge is pragmatically organized so that it is crucial to pay attention to what a person does and to the way he/she organizes his/her behavior when facing concrete situations. According to this theoretical standpoint, an individual's cognitive structure is continuously modified through his/her own experiences, which in agreement with Ausubel (1976; 2002) emphasizes the role played by prior knowledge in the knowledge construction processes, thus, Vergnaud's theory pertains to the constructivist paradigm.

He believes that knowledge is organized in *conceptual fields* defining them as a formal and heterogeneous set of problems, situations, concepts, relationships, structures, contents, and operations interconnected and presumably interwoven during the acquisition process (op.cit). They are, then, units of study that are helpful to attribute meanings to acquisition problems and to observations related to conceptualization. Vergnaud (op.cit) maintains that conceptualization is the central nucleus of cognition, that is, knowledge is constructed around concepts so that it is strictly necessary to pay much attention to the conceptual aspects of the schemes and to the conceptual analysis of the problem situations for which learners develop their schemes, both in formal teaching and in everyday life. In agreement to Vergnaud's ideas (1998), we can say that: a) a concept does not form itself within just one kind of situation; b) it is not possible to analyze a given situation with the use of only one concept; c) the construction and appropriation of all the properties of a concept or of all the aspects involved in a situation are comprehensive and lengthy processes.

In this theory, the relevance of the subject's *action* is emphasized as a mediator of conceptual evolution. Therefore, it is fundamental to face students with a variety of diverse situations in different degrees of complexity and whose response calls for the availability of specific concepts, as in the case of this research those related to cosmological models. This underlying idea is the key factor for the methodology applied here since its main goal has been to attain an improvement in the teachers' mental representations in comparison to the ones presented during the exploratory stage. Concept maps are relevant tools to analyze the knowledge individuals have in their minds (Cañas, 2005; Novak, 1998), and for this reason they were used in the methodology of the activities developed in the Planetarium with the teachers involved in this research.

As a follow-up to what has been already set forth, some ideas that are shared by these two theories—mental models and conceptual fields— will be concisely presented.

2.3 Which elements are shared by the two theoretical frameworks?

In accordance to Greca and Moreira (2003), we point out some commonalities in these two theories, which have guided this research project and have brought about relevant issues in its methodological implementation with the teachers, such as:

- A biological conception of the cognitive process: Johnson-Laird (op.cit) assumes that our world experience is a consequence of *natural selection*, while Vergnaud (op.cit.) uses the Piagetian concept of *adaptation* as a way of generating knowledge. Natural selection and adaptation are biological concepts applied, in both instances, to mental processes and are linked to the concept of evolution.

- Both authors maintain critical views on the Piagetian idea that reduces explanations of cognitive functioning to logical rules, and the two of them attribute to the contents of knowledge itself a crucial role in the individual's conceptual development.
- They also share ideas about the role of representations as an interface between the subject and reality. Actually, Johnson-Laird (op.cit.) believes that the human mind represents the world and it does so by means of a threefold code: propositions, images, and mental models. Vergnaud (op.cit.) states that knowledge construction comprises a progressive construction of explicit or implicit mental representations that are homomorphic to reality in some aspects but not in others.
- These authors emphasize the role played by concepts and their construction. Johnson-Laird holds that there is a hierarchical organization in the person's conceptual structure from which it is possible to get to the conceptual primitives. Vergnaud asserts that concepts are pivotal for comprehension and necessary in the search for solutions to concrete situations.

3 Research methodology

The methodological focus is mostly of descriptive and interpretative characteristics in agreement with the aims of this research. The research sample comprised teachers who attended academic activities offered by the Planetarium of Barranquilla, Colombia. Data from diverse sources were analyzed according to the following parameters: *concepts involved and linkages established among them; theoretical issues handled by the subjects in the explanation of situations and phenomena; stability or permanency of the models in time and along a variety of situations*.

The concept maps, which were interpreted here according to the theories that underlie this research, refer to the five teachers (identified by JC, RG, OM, JG, and AF). Although we will not analyze the totality of instances due to the scope of this paper, this does not prevent us from reaching some conclusive considerations which support the use of concept maps as instruments to bring about the teachers' representations of models of the universe and their evolution by means of a mediation offered by a teacher, in this case the researcher him/herself.

4 Descriptive analysis of the teachers' concept maps about cosmological models

Concept maps are diagrams that indicate relationships among concepts. They can be seen as hierarchical diagrams that reflect the conceptual organization of a body of knowledge, or part of it (Novak, 1998; Moreira, 2006). According to these ideas, we have privileged in their interpretation the conceptual structure they presented, taking into account the elements included as concepts and the linkages established between and among these concepts.

Concept maps and their descriptions, developed during the activity sessions attended by this group of teachers at the Planetarium, in Barranquilla, Colombia, are presented here. We analyze the sequence of maps drawn by teachers JG and AJ as evidences for the validity of this instrument and also to inquire about how it can allow us to infer the evolution of the teachers' representations of the universe when a conceptual enrichment is provided in the activities offered in the Planetarium.

4.1 Concept maps of teacher JG.

The first map was drawn and presented in a group session in which the teacher himself explains and justifies its elements and linkages. We can infer that, according to the concepts and linkages it contains, this teacher holds an origin for the universe in which it transforms itself, evolves and expands itself both in time and in space. This process, according to this teacher's cosmological conception, makes possible the formation of matter and energy and the generation of forces. Figure 1 shows JG's first concept map. These maps are shown in its original form and they have not been corrected to respect the teachers' own representations considering that their quality expresses the content of the teachers' knowledge.

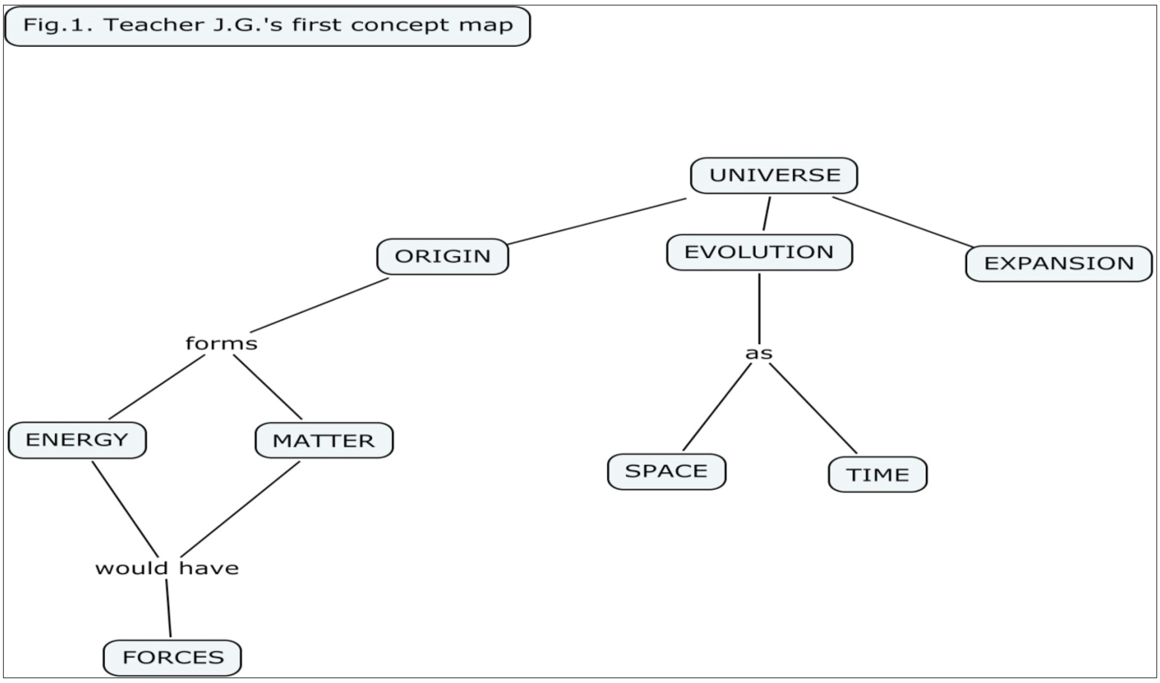

Figure 1. Teacher J.G.'s first concept map.

The second and the third maps drawn by the same teacher express more clearly ideas related to a conception of the universe that seems closer to the standard cosmological model. We can notice in them a greater number of conceptual elements that show better linkages among them than the first one. We stress that both the first and the second maps were drawn in one of the meetings with the teachers at the Planetarium, whereas the third one was not drawn within the formative spaces of the Planetarium. Figure 2 and 3 depict these representations about the universe drawn by teacher JG.

The first assessment they might offer us concerns the conceptual development experienced by this teacher throughout his consecutive maps. The analysis of teacher JG's concept maps allows us to convey that these maps can be indications of an evolutionary process in the representations JG holds about cosmological models, expressing the presence of new concepts in his cognitive structure that have enriched his representation of the universe.

According to the theories that underlie this research, the fact that the new information managed to get structured in the mind would point out that more stable mental models have been formed, which emerge when a person is faced with new situations and evolve towards conceptual schemas for the universe because of their functionality. Nevertheless, if we want to confirm these hypotheses new steps and activities are required since conceptualization processes are progressive and extensive.

4.2 Teacher AF's Concept maps

Figures 4 and 5 show Teacher AF's concept maps whose analysis might allow for some inference about the evolutionary process of conceptualization during the activity sessions in the Planetarium.

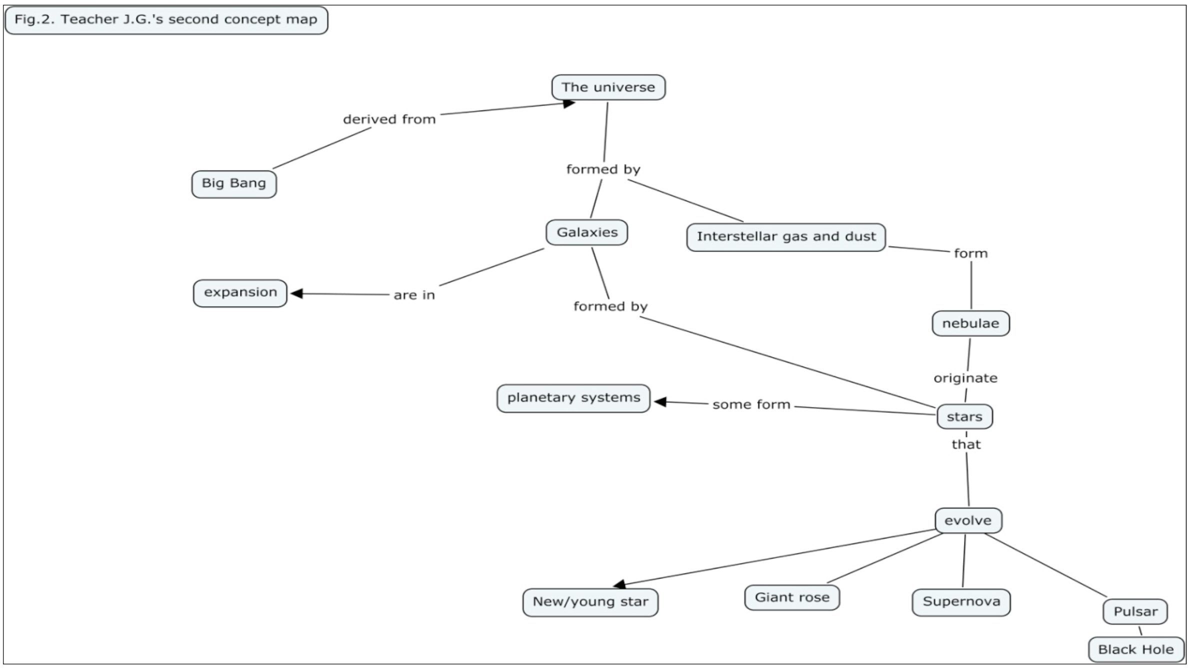

Figure 2. Teacher J.G.'s second concept map.

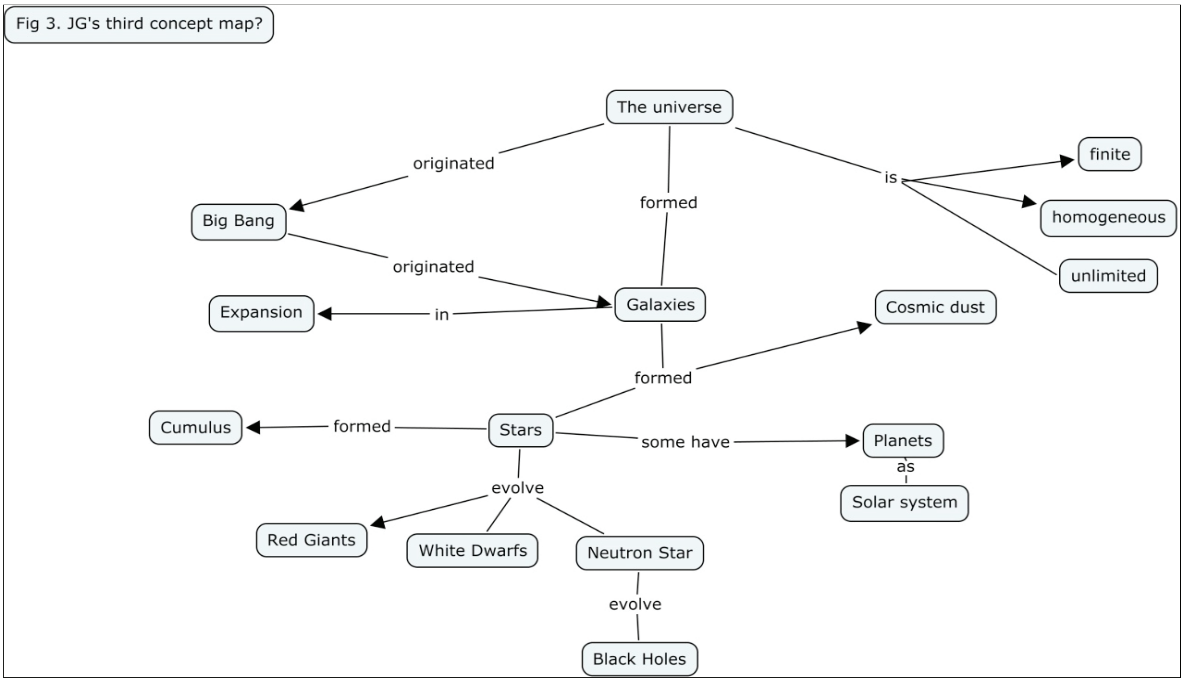

Figure 3. J.G.'s third concept map

It is possible to notice in teacher AF's concept maps that his second map is a complementation of the first one since both refer to the origin and constitution of the universe based on the standard cosmological model, although it includes elements that are part of modern scientific theories. The teacher himself stated that *the readings done have allowed him to add elements he had already incorporated to his cognitive structure when the understanding of linkages among these elements became clearer.* We can notice a progressive conceptual evolution concerning his initial representation of the universe.

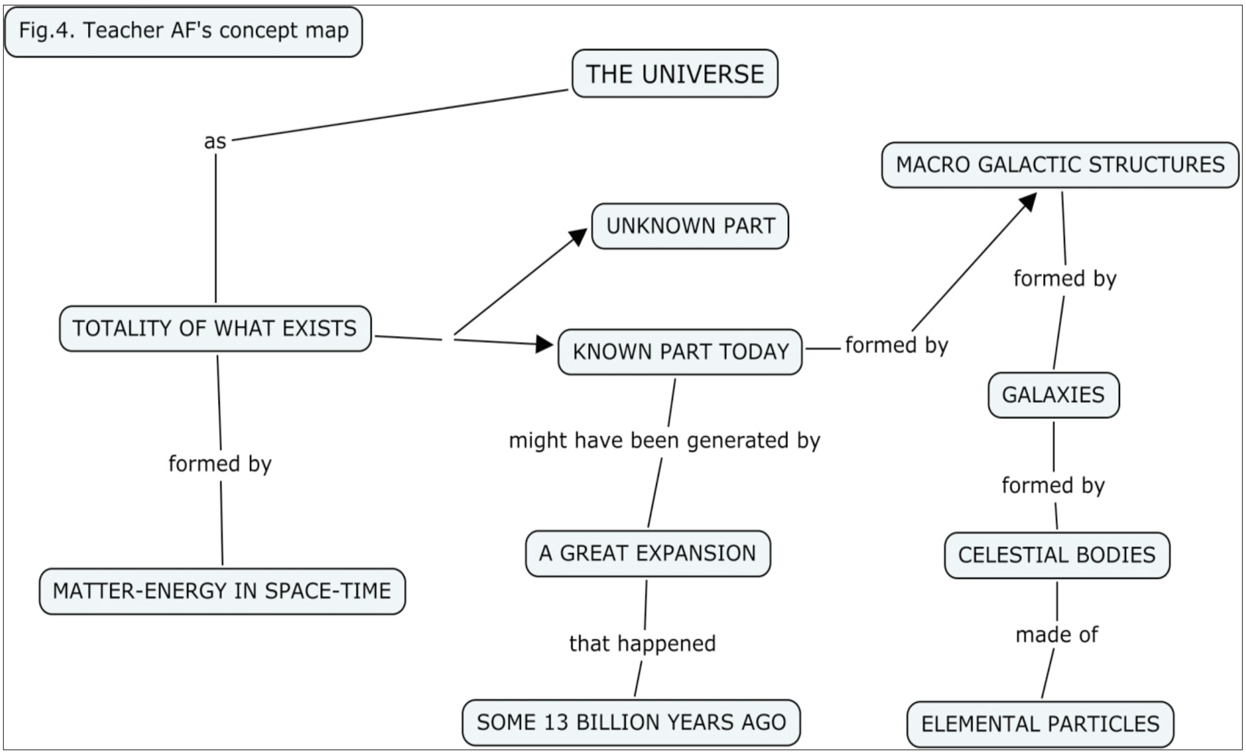

Figure 4. Teacher A.F.'s first concept map.

5 Summary

Although for reasons related to the limitation of length of this paper concept maps drawn by just two of the teachers have been presented here, we can consider them as indicators of the representations of the sample of teachers in this research, and this can lead us to bring to discussion some elements about the potential of concept mapping as an instrument to make explicit the knowledge these teachers had in their cognitive structure about models of the universe. The concept maps shown here might be considered to have a reasonable approximation to the representations hold by these teachers in their cognitive structure, though not particularly precise or complete (Moreira, 2006). Concept maps are suitable instruments to visualize concepts and their relationships with other concepts available in the person's cognitive structure, thus, allowing for the construction of new meanings in a given field of knowledge.

Comparative analysis of the concept maps of the teachers who participated in the Planetarium activity sessions suggests that the elements and linkages established among them can indicate a difference in the conceptual clarity of their representations. Mental models can be viewed as functional knowledge since they can reveal the degree of comprehension that a person has about an event, a situation, or of a system, and how and why it works that way, so we have to agree that the education in sciences offered to students in different levels of schooling, in Colombia, might not allow them to develop scientifically accepted mental models and/or conceptual schemes about the universe. Consequently, there is a need to promote educational policies to improve science education so as to grant teachers in all educational levels the opportunity to anchor scientific (in reference here to cosmology) knowledge in their mental structure. Johnson-Laird (1983) states that more complete and coherent relations imply better perceptions and visualizations.

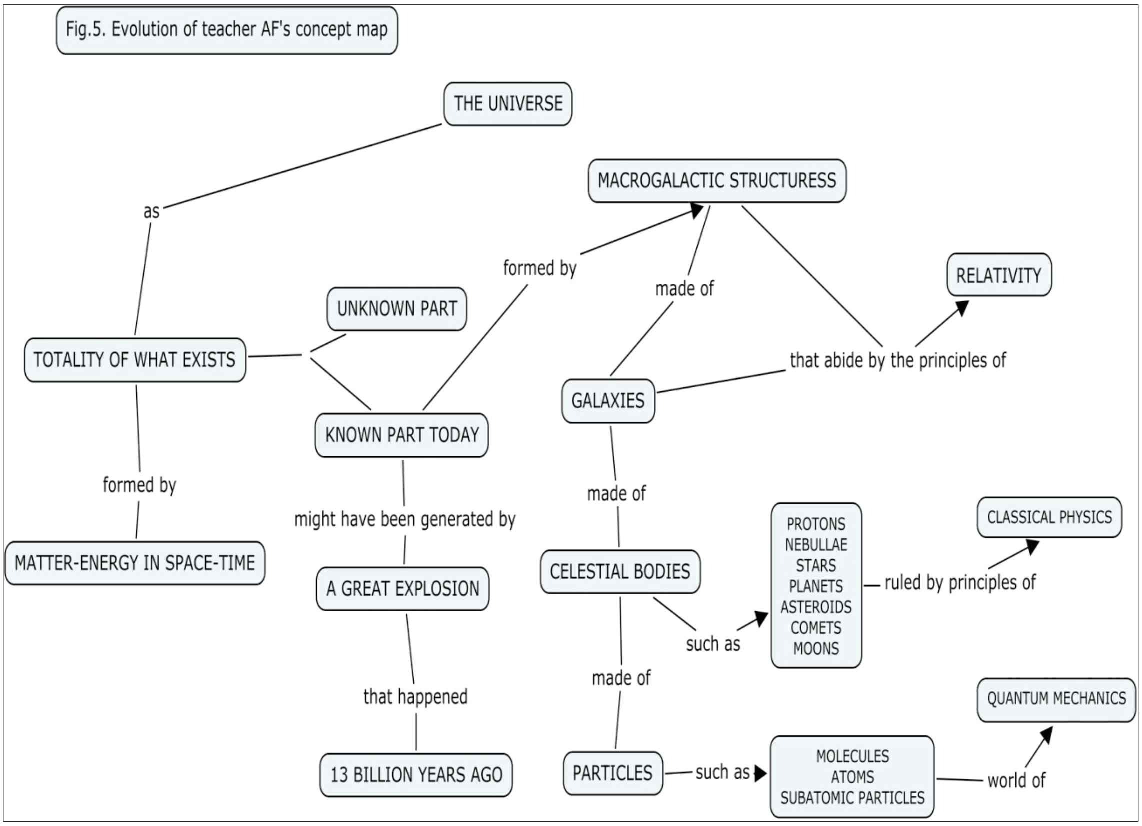

Figure 5. Teacher A.F.'s second concept map.

We also compared concept maps when there was a diversity in the teachers' educational background, since they all had a teaching degree (Licenciature) but have majored in different areas of knowledge, such as social sciences, biology, and chemistry. There are representations that differ in their conceptual content, and this might lead us to suppose that beyond the individuals' vocational formation, in their external representations of the universe there are elements that indicate and determine the structure of the representations these persons develop which may not derive from the formal education they have received.

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CONCEPT MAPPING AS AN INNOVATION: DOCUMENTS, MEMORIES AND NOTES FROM FINLAND, SWEDEN, ESTONIA AND RUSSIA 1984 – 2008

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Abstract. Novakian type of concept mapping is studied as an innovation adapting Rogers' theory of communication and diffusion of innovations. The main data and conclusions are based on documents, memories and notes from Finland, but also from Sweden, Estonia and Russia 1984 – 2008. One of the main innovative uses of concept mapping in Finland has been its use and development as research method and quality tool. Concept mapping is compared to other graphic representation tools, in particular mind mapping and clustering. In the article the main features about history of concept mapping in Finland, Sweden, Estonia and Russia 1984 – 2008 is presented based on documents. Based on scattered evidence mind mapping is more spread and used than concept mapping in all these countries. In Finland concept mapping has stronger position than in Sweden, Estonia and Russia. More research is needed to reveal history and development of Novakian type of concept mapping both regionally and globally.

1 Introduction

Research on the diffusion of innovation is the study of how, why, and at what rate new ideas and technology spread through cultures. In this paper the innovation is Novakian type of concept mapping from 1980s. The history and spread of graphic knowledge representation tools in general are much longer and wider (Åhlberg 2007).

There is disagreement when proper concept maps were invented. Åhlberg (2004, 25) researched on this issue and came to conclusion:

> *"It is commonly known that concept mapping was developed at Cornell University. Stewart, Van Kirk, and Rowell (1979, p. 171) claim in The American Biology Teacher that they developed concept maps. However, in their concept maps the links were not named and no propositions were formed from concepts. In that same journal, Novak (1979, 1980) later published two articles in which he referred to Stewart, Van Kirk, and Rowell (1979). He also presented examples of concept maps, but the links were still unnamed. However, in Novak (1981, p. 14) the links were named, and meaningful propositions were created out of concepts. This is the form of Novakian concept maps that has been spread globally. In fact, Novak and Gowin (1984) were very influential in spreading it all over the world."*

I had seen the articles of concept mapping when they were published, but it was the book (Novak and Gowin 1984), which put me thinking: This is what my pre-service teacher education students really need. Too often they told me that they do not need studies of statistical methods or research methods in general. But the need for concept mapping ought to be self-evident. I soon realized that not all students were able to value this empowering tool. However, I myself was very convinced about its strong properties to express accurately everything that can be thought and expressed in verbal or written form. What was nice about concept mapping was that it revealed hidden core concepts, if you know how they can be counted from the number of links connecting concepts to other concepts. Concept mapping became to me a research method, as general as spoken or written language. For me it is an innovation to monitor and promote quality of learning and thinking. I have tried to spread this educational research innovation in all my teaching, research, seminars, conferences, that I have participated, and cities and countries where ever I have travelled since 1984. Next I discuss only three examples from North-Western Europe.

2 Concept mapping as research method

Åhlberg (1990b; 1993 and 2007) has published history and comparisons of main educational methods and techniques of knowledge representation. In theory of science, 'technique' is a narrower concept than 'method'. In 1980s, I regarded concept mapping as a technique for specific purposes, but later on I started to regard it as a very general method that can be applied for many different purposes. Mind maps developed and registered by Tony Buzan (1974; 2000) are often confused with concept maps, although these intellectual tools are very different. Åhlberg and Ahoranta (2002) and Åhlberg (2007) have compared these tools in detail. During 1989 – 2008 I have supervised tens of Master's theses (e.g. Malinen 1997; Mäkinen 1996) and many Doctoral Dissertations (e.g. Kankkunen 1999, Ahoranta 2004 and Salmio 2004) in which concept mapping has been used as a research method.

Primitive concept maps without link phrases are often misleadingly called concept maps. In Novak's research group in 1970s these kinds of primitive concept maps were used as documented in Novak and Gowin (1984). However from Novak (1981, p. 14) onwards all proper Novakian concept maps have used link phrases. Rico (1983 – 2008) has registered trademark for a technique called clustering which reminds of primitive concept maps: only concepts linked by lines, no linking phrases. Novak (1998) tried to register his original version of Novakian type of concept mapping (links mostly without arrowheads) but the application did not succeed.

Åhlberg (1990b and 1993a) presented in context of research on textbooks the idea of transforming a text proposition by proposition into concept maps. One of the main options in research use of concept mapping is transformation proposition by proposition from spoken and/or written text. This reveals hidden conceptual structures of text. E.g. key concepts can be objectively counted from number of links.

3 Finland

Since 1984 I have taught and developed concept mapping as a research method at University of Helsinki, first as lecturer, then as an adjunct professor (docent). During these years I published as far as I know the first concept maps in Finland (Åhlberg 1988 – 1989c). As Poom (1992, 58) reminds, Åhlberg (1987) had even before that distributed manuscripts in which there were concept maps in Finnish. During years 1989 – 2004 Åhlberg was Professor of Education at University of Savonlinna. In 1993 Åhlberg had a chance to visit Cornell University and Professor Joseph D. Novak. He learnt very much about concept maps and their history. Åhlberg developed a version of Novakian concept maps (improved concept maps), which uses always arrowheads with links to show in which direction concept map is to be read from concept to concept (Åhlberg 1987 – 2004). This type of Novakian concept mapping was used extensively later on in several doctoral dissertations, e.g. Kankkunen (1999), Ahoranta (2004) and Salmio (2004). Kankkunen (2001 and 2004) wrote also two papers based on the work I supervised using improved concept mapping.

In 1996 in Savonlinna Campus of University of Joensuu, a big international conference, Northern Call for Environment, was arranged. There Åhlberg taught concept mapping. One of the later on famous participants was Taina Kaivola, who used improved concept mapping in her doctoral dissertation (Kaivola 2000). Kaivola (2008) refers to history of concept mapping in Finland naming Åhlberg as an early adapter and active teacher of concept mapping. Åhlberg and Kaivola have used and promoted concept mapping as a research method (e.g. Åhlberg 1990a and 1990b; Åhlberg 1991a and 1991b; Kaivola & Åhlberg 2005; Åhlberg & Kaivola 2006a – 2006c). Little by little concept mapping spread among Finnish teachers and researchers. Nowadays concept mapping is well know in Finland and widely spread method of graphic representation of knowledge.

Physics teacher educators have developed a very special version of concept mapping from 1999 onwards (Väisänen & Kurkisuonio 1999, Niskanen 2007, Pehkonen 2007). Väisänen & Kurkisuonio (1999) refer to Åhlberg (1991). Åhlberg (1991) was published by Union of Mathematics, Chemistry and Physics Teachers of Finland. In that paper a Novakian concept map was used. Physics teacher educators use always arrowheads with links to show in which direction concept map is to be read from concept to concept like (Åhlberg 1987 – 2004). However the use on links in Väisänen & Kurkisuonio (1999), Niskanen (2007) and Pehkonen (2007) is very different from use of links in other fields of education and science. It is not ordinary language. It is not possible to read directly from one concept to another. They often use formulas as links. They admit that their use of concept maps is not Novakian. An explanation may be the following: Kurki-Suonio was a Professor of Physics who was interested in Physics Education. He used in Kurki-Suonio & Kurki-Suonio (1994, e.g. 159) graphic representations that used nouns as links between group of physical terms, that is an ordered association map. He seems never understood value of creating directly-read full propositions out of group of concepts. His main interest was in shared expert conceptual structure of Physics. They are often expressed as mathematical formulas.

On the other hand Lavonen (1996, 68 and 84) in his doctoral dissertation in Physics Education, uses concept map in the improved Novakian way that he had learnt in Åhlberg's courses during the end of 1980s. They both were members of a network for science education improvement called FINISTE (Finnish Innovations in the Science and Technology Education). Lavonen (1996) refers to Novak and Gowin (1984) and Åhlberg (1990). In the same FINISTE courses there were also teacher of physics Hannu Kuitunen from National Board of Education. He started to use improved Novakian concept maps developed by Åhlberg (1987 – 1989), e.g. Kuitunen (1993).

Even later on a PhD of Physics, Tuula Keinonen (2005) in her Doctoral Thesis in Science Education, used clearly improved Novakian concept mapping and improved Vee diagram developed by Åhlberg (1987 – 2004).

In 1990s, I was a member of the Finnish Society for Quality (Suomen laatuyhdistys) and I published with two of my university students a paper of concept mapping as a new quality tool (Åhlberg, Nevalainen, & Mäkinen 1997). Elina Mäkinen (1996) used improved Novakian concept mapping in her Master's Thesis. She later became an officer in the Finnish Society for Quality (Suomen laatuyhdistys. The theme of Mäkinen's Master's Thesis (1996) was continual quality improvement in Savonlinna. Department of Teacher Education (University of Joensuu). We even had a couple of seminars arranged by the Finnish Society for Quality for business people. At that time the Finnish Society for Quality was selling Åhlberg (1997) in which improved concept maps were presented as a new quality tool. Some business people became interested. However, many of them were already users of mind mapping. They enjoyed comparison of different knowledge representation tools, but were already comfortable with mind mapping. It was enough for their purposes.

In 2004, I met Dr. Alberto Cañas and her wife Carmen Collado. I asked and arranged them several time to visit Finland. I learnt how to use CmapTools (Cañas *et al.,* 2004). I arranged two persons from my research group to translate CmapTools to both main languages of Finland: Finnish and Swedish. Mr. Jarkko Mylläri, MA (Education) translated CmapTools into Finnish. Lecturer Romi Rancen MSc (Forestry) translated CmapTools into Swedish. I arranged with help of many persons the Ministry of Education to pay one public CmapTools server to Teacher Education in Finland and the National Board of Education to pay another public server for Finnish schools, teachers and pupils. The initial idea for The Third International Conference on Concept mapping (CMC2008) emerged in Spring 2007 during a visit to my research group by Dr. Alberto Cañas, Carmen Collado, and Prof. Priit Reiska.

Hopefully in later research history of different versions of concept mapping in Finland will be researched on, in more detail.

4 Sweden

I visited Universities and University Colleges in Stockholm, Uppsala and Härnösand several times during years 1988 – 1993. I taught there improved concept mapping in several seminars and conferences. I studied Swedish educational research literature and I found one earlier writer of concept maps (in Swedish begreppskarttor) than me: Dahlgren 1988 and 1989. I published in Swedish an article about concept mapping and argumentation analysis (Åhlberg 1993). As far as I know there were only Dahlgren's (1988 and 1989) before me as Swedish publications about concept mapping. I met in 1990s Gustav Hellden in European conferences where I used concept mapping in my presentations. Later on I met him at Cornell University 1993, but he had not yet started to use concept mapping himself. Later on he has learnt concept mapping (e.g Magntorn & Helldén 2006).

Using Swedish version of the Google http://www.google.se/ and keyword 'begreppskarta' we found very little hits in Sweden, in April 30, 2008. The first hit was from Finland, and the site was University of Helsinki, and it uses improved Novakian concept mapping in the sense of Åhlberg (1988 – 2004). The site directly refers to Åhlberg (1990b). Concept maps have never become as popular in Sweden as in Finland. Later research hopefully may illuminate reasons for this.

5 Estonia

I was invited to visit Tallinn Educational University in 1991. I had there a presentation about concept mapping. Later on a student came to Savonlinna from Tallinn Educational University to study more about improved concept mapping. Her name was Katrin Poom. In 1992 she published an article about her use of improved concept mapping in Estonian (Poom 1992). Using Estonian version of Google (Google.ee) and Estonian word for concept map (Moistekaart) as keyword, we found no proper concept map links in 30.4.2008. Concept maps have never become as popular in Estonia as in Finland. Mind mapping seem to be much more popular. Later research hopefully may illuminate reasons for this.

6 Russia

Åhlberg's university students have used often concept mapping in their Masters' Theses. E.g. Malinen (2001) studied concept mapping in Russian school in St. Petersburg. During 1995 – 1998 Åhlberg taught concept mapping to many Russian school and university teachers both in Savonlinna Campus of University Joensuu and in Russian schools during international seminars of Environmental Education (e.g. Åhlberg, Pölönen & Hynninen (Eds.) 2000). Concept maps have never become as popular in Russia as in Finland. Later research hopefully may illuminate reasons for this.

7 Communicating for innovations

Rogers (1983 – 2003) claims in his theory of communication and diffusion of innovations that adopters of any new innovation or idea could be categorized as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). Åhlberg in the 1980s was first an early adopter, and then a co-innovator when he with his research group created what they called improved concept mapping. There has been heavy struggle for popularity between mind mapping and concept mapping also in Finland. As far as I know there are no empirical data concerning proper use of concept mapping vs. mind mapping in Finland, Sweden or Estonia. Based on scattered observations in many university courses and scientific conferences, my hypothesis is that Tony Buzan's (1974 – 2000) mind mapping technique is more widely spread than real Novakian concept mapping (Åhlberg 2004). Many people say that they are familiar with concept mapping, but when they demonstrate their use of it, they clearly are using rather mind mapping not concept mapping. Very common is also what Rico (1983 – 2008) calls clustering.

8 Conclusions

Concept mapping was developed at Cornell University in 1970s, and its best known Novakian version in 1980s. It was an educational innovation which has spread in different ways in different countries. It is important to know better the history and spreading of concept mapping as innovation. It is important also to understand more deeply reasons for development and spread of different versions of concept mapping. There is a family tree of concept mapping in each country and it can be revealed by later educational research.

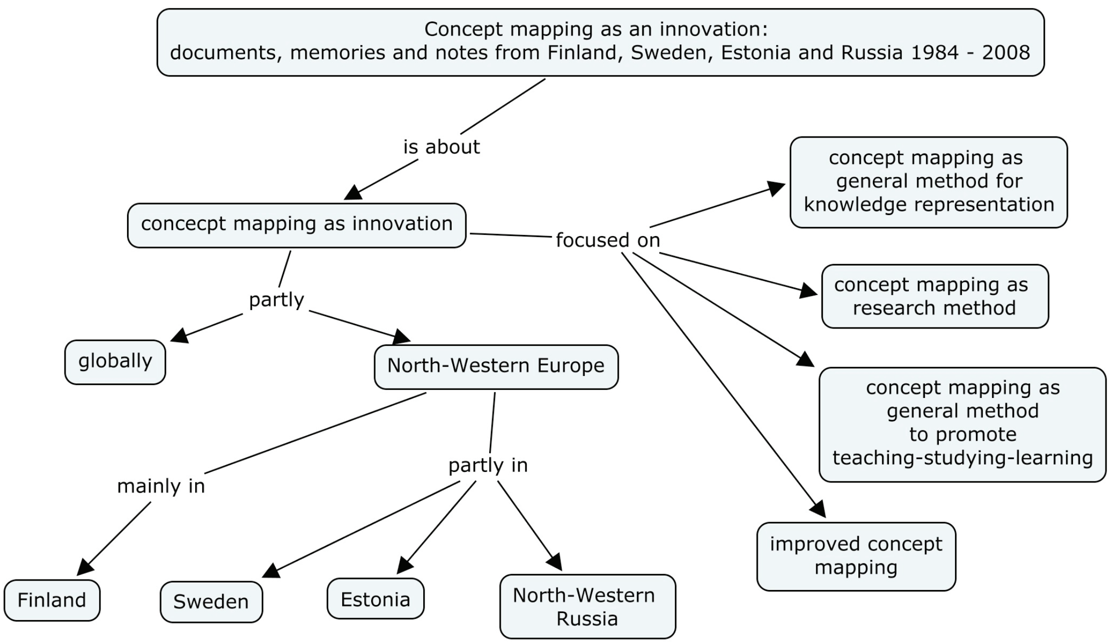

Fig. 1. Main ideas of the paper presented as a concept map. The most central concept is 'concept mapping as innovation'. It has seven links with other concepts. The second in centrality is the concept 'North-Western Europe. It has five links with other concepts.

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CONCEPT MAPPING IN MATHEMATICS: TOOLS FOR THE DEVELOPMENT OF COGNITIVE AND NON-COGNITIVE ELEMENTS

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Abstract. The present work deals with a teaching experience with students beginning their formation in engineering at a university level. It deals with a non traditional course of Calculus using concept mapping as a teaching tool. Considering learning by the students to be a development of both cognitive aspects as well as non-cognitive aspects, concept mapping was integrated into the course in order to develop different components of logical reasoning and spatial orientation, as well as to develop a component to the non-cognitive sphere: the self-concept. The teaching experience described represents a phase of experimentation forming part of research into the teaching of mathematics. It is an attempt to show that in the framework of the cognitive paradigm of education mathematics and teaching strategies with concept mapping as a tool can be considered as a means to the development of thought and affectivity, that is to say, for the cognitive and non-cognitive.

1 Introduction

At the different teaching levels, the learning process in mathematics, or any other content, implies the development of cognitive and non-cognitive elements, that is to say, elements of thought and elements of affectivity. Polya (1972) asserts that it is not right to consider the solution to a problem to be merely an intellectual question. The author explains that in the activities of mathematics and science, the emotions play an important part. To resist years of work and eventual failures, Polya (1972) pointed out certain intellectual development is necessary but also a great strength of will. In the field of learning of mathematics the development of intellectual capacity is important, but also affective aspects can motivate the student for the activities and tasks. These basic elements of affectivity can be stimulated in the classroom during the teaching and learning processes.

During the study of mathematics cognitive elements can be developed such as logical reasoning and spatial orientation. In other words, the basic stages of thought can be developed such as induction, deduction, placing, locating and graphic expression, among others. This is what can be appreciated in the cognitive paradigm of education. From this perspective the teaching of mathematics can be understood as one way, or particular ways, of proceeding in the classroom in order to contribute towards learning, understood as the development of various cognitive capacities.

But during the learning experience in the classroom, what is known as the self-concept, considered as a non-cognitive element belonging to the field of motivation and affectivity, can be developed. Motivation achievable in the class room coincides favourably with affective factors of the student's personality, which in turn helps the learning process. The self-concept is considered to be an affective factor which should not be forgotten at any teaching level. This affective factor (non-cognitive) is not to be found in isolation; as Nuñez (1998) states, it is an element that influences cognitive strategies.

A good range of strategies in the classroom leads to teaching that favours learning of quality. This can be translated, according to Goleman (1995), as a development of elements both intellectual (cognitive elements) as non-intellectual elements (affective elements such as self-concept).

2 Concept mapping in the learning of mathematics

There are different ways of using concept mapping as a tool to support the learning of mathematics in the classroom. The following describes a particular way of applying concept mapping, which can be summed up as follows:

- Concept mapping elaborated by the teacher serves in the main as a guide to reinforce the development of thought elements that are implicit in mathematical content (cognitive elements).

- Concept mapping developed by the students as classroom activities, supervised by the teacher, serve as reinforcement in the development of affective factors such as self-concept (non-cognitive elements).

In this same section methodological aspects will also be presented as well as results obtained during teaching experiences with beginning students in engineering.

2.1 Concept mapping for the development of cognitive elements.

One must not forget certain ideas about concept mapping and its applications in the teaching context. It is important to mention that concept mapping (Novak, 1998) plays a key role in the classroom in the representation of knowledge. Concept mapping is a useful aid for the teacher since it is a good tool in how to organize the knowledge and show it (Novak, 1998), but it also helps the students in their efforts by being able to learn the contents in a constructive and meaningful way, quality learning (not by rote). In this sense the use of concept mapping in the classroom together with a group of teaching strategies allows the development of capacities and cognitive skills in the students (Román, 1988), that is to say, a development of thought and a development of elements of cognition. This can be translated into an adequate storage of the material in the student's cognitive structure to be available when needed (Ausubel, 1988). One can say that the performance of the teacher, as a mediator in the classroom, guided by concept mapping, leads to cognitive intervention.

How does the teacher act guided by concept mapping in order to develop the thought processes of the students? The teacher has to prepare his own concept mapping with the contents of the mathematics where concepts appear with different levels of generality, with graphics or images associated with the concepts and concrete examples included. The classes are not just a question of presenting the students with the concept mapping created by the teacher. His mapping is only a guide to teaching. One has to present the material in the mapping little by little trying to go from the particular to the general, naturally amplifying and enriching the information. In other words, move from the information in the lower part of the mapping to that in the upper part. The idea is to present particular information accessible to the students' level in order to be appreciated later with the support of images and/or graphic representations and arrive at the presentation of concepts. It is very important to take into consideration that graphics or images contribute to the visualization of the concepts, to the learning of mathematics (De Guzman, 1996). In addition, moving from the particular to the general promotes the realization of inductive thought processes, which means a development of thought or cognitive intervention (Feuerstein, 1995).

The intellectual work carried out by the teacher when creating his maps implies the consideration of the teaching-learning process, in other words, finding out how the student learns in order thereby to design his teaching. The stages of perception, representation and conceptualization are considered to be basic stages in learning (Román, 1988). The concept mapping is a guide to favour these stages in the classroom. By promoting perception, representation and conceptualization, in this order, inductive thought processes are put into practice.

For the teaching of mathematics concept mapping prepared by the teacher must take into consideration the learning profiles of the students (Krutetskii, 1976). They must contain both visual elements (geometrics) and analytical, to help those students who have a strong inclination towards the visual aspects of mathematics and to attend those inclined to analytical reasoning.

To sum up, the teacher must present both facts and concepts. As a particular interpretation of Piaget ideas, it is considered that by contrasting facts with concepts and concepts with facts, inductive and deductive processes are carried out, contributing to constructive learning (Piaget, 1979). The teacher must present the concepts beginning from the lower levels and leading to the higher levels of generality. As Ausubel explains, the inductive and deductive thought processes are empowered when the information is disposed respecting the conceptual hierarchies, achieving subordinated and supra-ordered learning, moving from the particular to the general and vice versa (Ausubel, 1976). The teacher must also initiate from a stage where the student can handle the information in order to arrive at abstraction, passing through the visuals supports. From the point of view of Bruner and the theory of learning by discovery, moving from an inactive system to a symbolic system allows the development of inductive processes (Bruner, 1988).

Figures 1, 2 and 3 in the following pages show some examples of concept mapping constructed and integrated into the process of the teaching and learning of mathematics during a course of calculus. It is important to point out the teaching and learning of mathematics not only centres on concepts, but it must also pay much attention to exercises and problems as well as the development of the abilities to resolve them. For this reason, concept mapping not only covers concepts, but it is also important to show aspects of the procedure for problem solving.

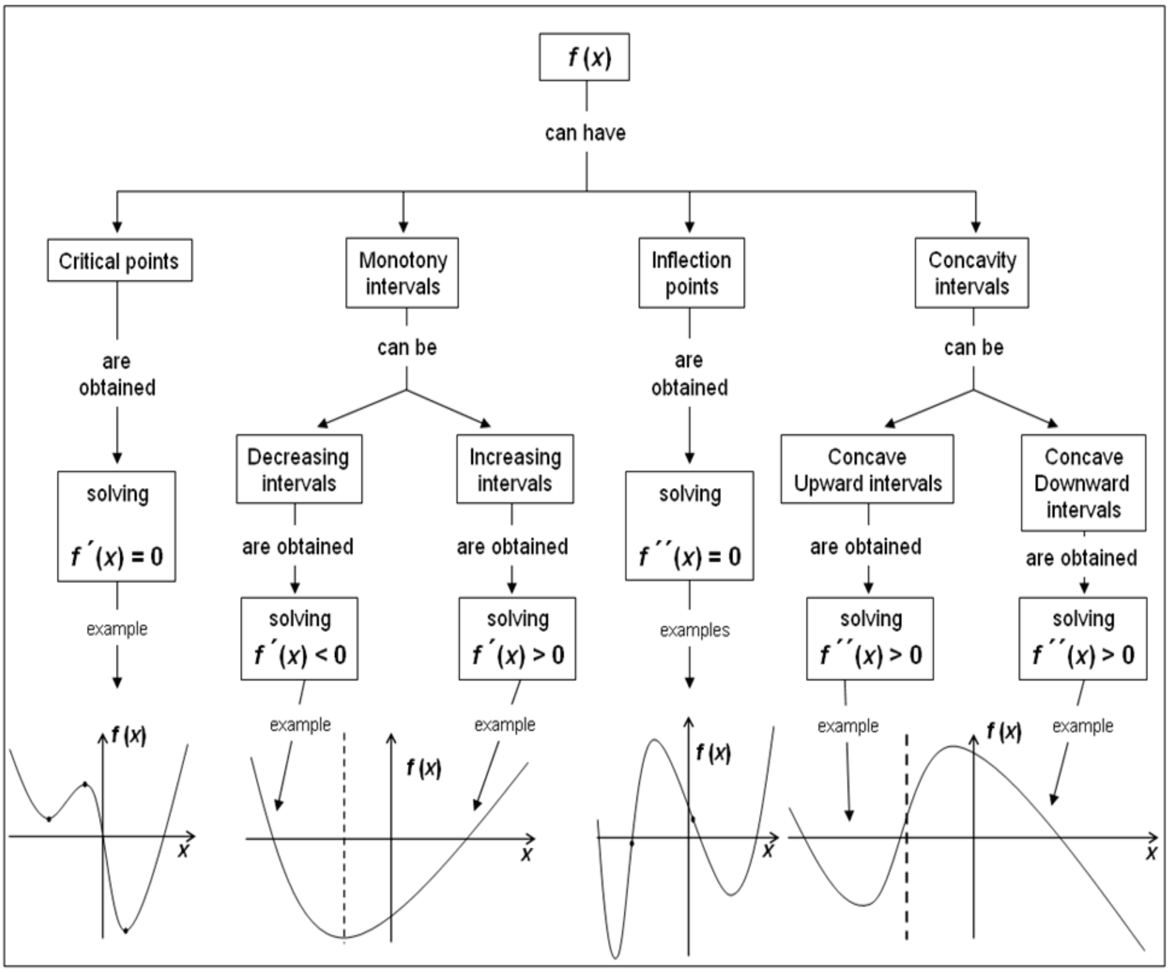

Figure 1. Concept mapping: "Elements of a function".

2.2 Concept mapping for the development of non-cognitive elements.

Teaching practice has not paid enough attention to the emotional impact of the learning of mathematics. In fact, most of the literature dealing with the subject of research into the learning of mathematics only takes into consideration the cognitive aspects, forgetting the non-cognitive elements (affectivity), mainly because the study of mathematics is prejudged to be merely intellectual or cognitive.

On the other hand, various authors (Núñes, 1998) point out that the learning of mathematics in the atmosphere of the classroom has innumerable connotations, that mainly refer to anguish, suspicion, boredom, and what is worse, personal beliefs about the lack of cognitive competence, (believing one is no good at mathematics). It is a question of connotations that belong to the ambience of motivation and affectivity. From that point of view, one can insist that the learning of mathematics is not only a question of cognitive capacity.

Methodological strategies for the teaching and learning of mathematics must be designed as an interactive system in which cognitive capacities and feelings combine. Gómez (2003) points out that in the degree that such aspects become integrated, relationship and pedagogical communication established between the teacher and the student, represent a factor that facilitates the acquisition of mathematical concepts and abilities. But also, this interactive system favours the development of affective elements in the students such as self-concept. In the context of the classroom the self-concept can be understood as the interaction of the student with the others and also as the influence he receives during coexistence. Self-concept is a dynamic and active construct of the student's physical, cognitive and emotional history.

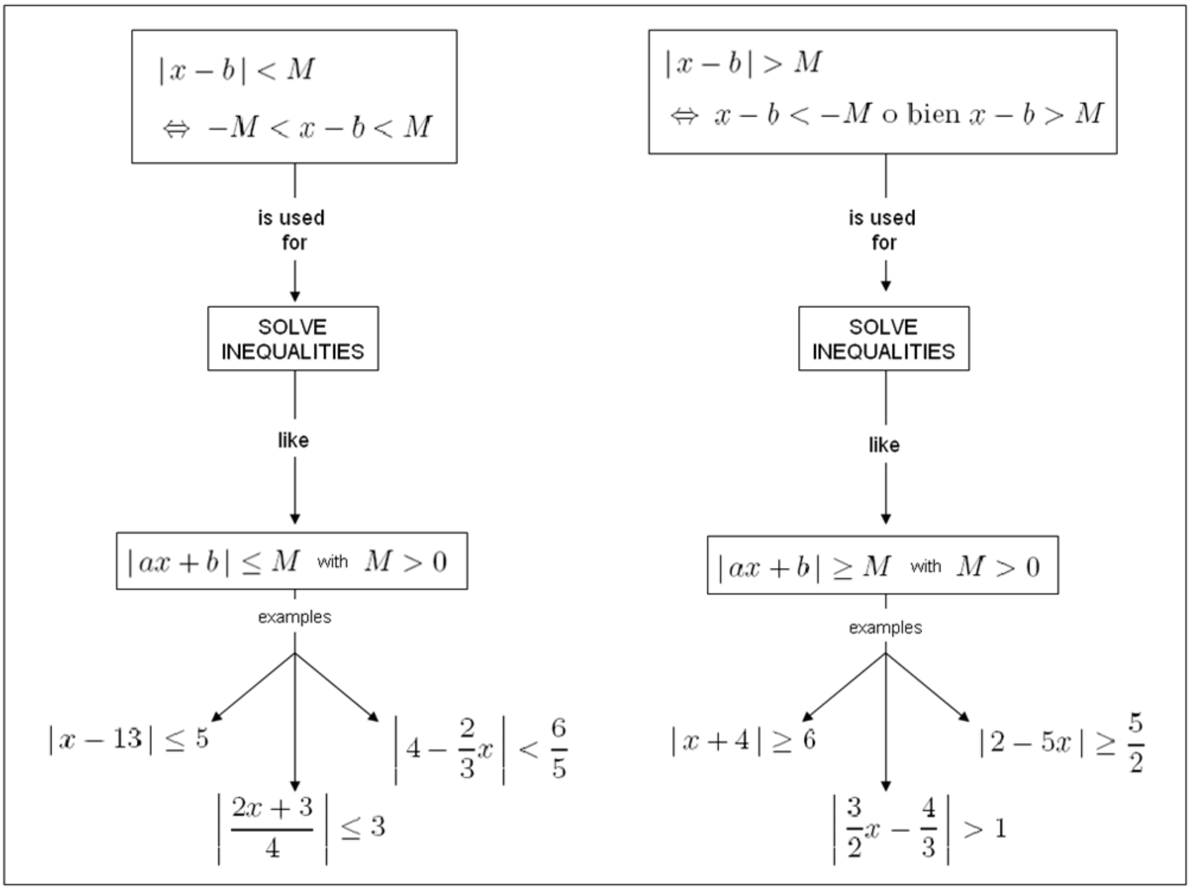

Figure 2. Concept mapping: "Solution of certain inequalities".

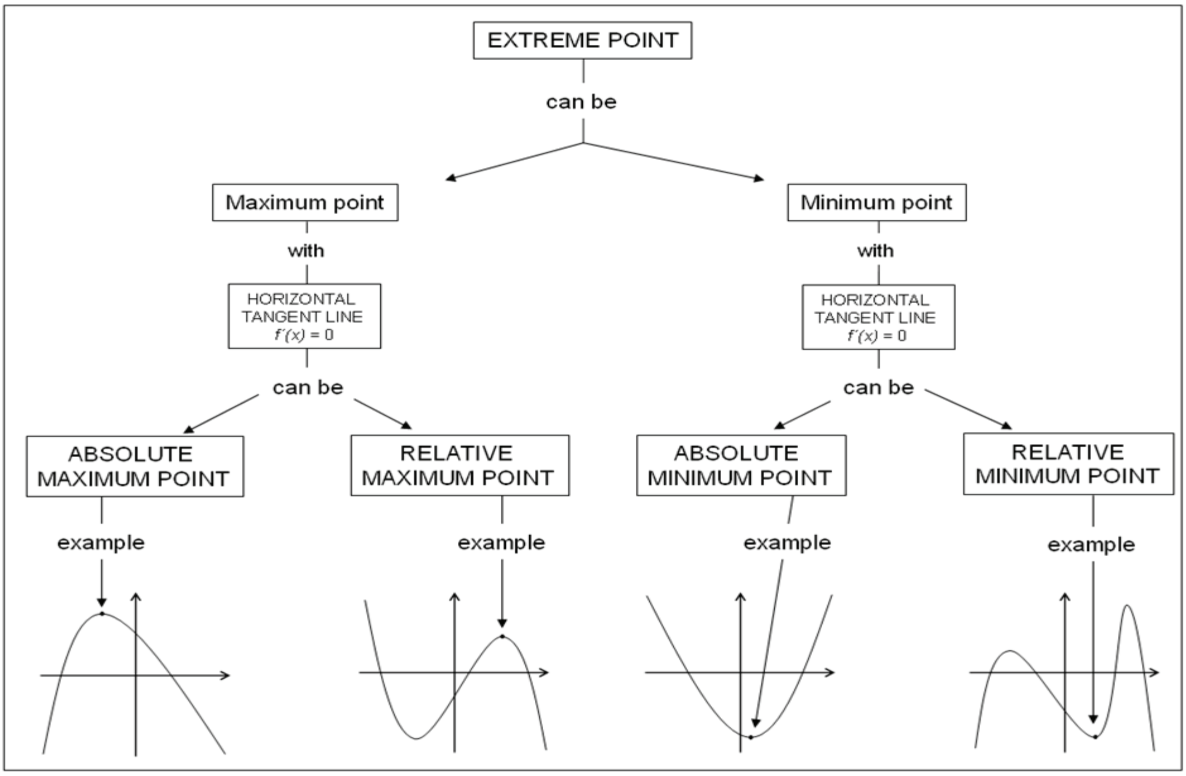

Figure 3. Concept mapping: *"Extreme point"*.

Concept mapping integrated into the teaching activities influences learning, understanding this as the development of cognitive and non-cognitive elements. Especially the concept mapping the students can develop as activities in the classroom, under the supervision of the teacher, helps mainly in the development of affective factors, such as self-concept.

The students' activities, collaborating with each other and the teacher, such as the preparation of concept mapping and the development of exercises or problems, represent a significant cognitive act and have an effect upon motivational aspects. A significant cognitive act has an effect upon self-concept (González, 1987).

Taking up some of Rogers' ideas (1990), the teacher's role as the facilitator of knowledge can create cognitive conditions and ambiences favouring the development and construction of learning. Rogers (1990) describes the interaction between the teacher and students as a horizontal relationship and not hierarchical, in that the communication is conceived as part of the pedagogical relationship, and in that the intellectual, emotional and affective experiences are integrated. The basic idea is the proper development of the self-concept should interact significantly with the motivational dimension and cognitive effort, which reflects upon the optimum and significant learning processes.

2.3 Educational experience with concept mapping for the study of mathematics

It is obvious one can state that the subject of mathematics is of great importance, among other reasons for its application in science, in technology and contexts in daily life. But in addition, as with other subjects, mathematics is of great educational value at all levels, since it allows for the development of thought. In addition, at all levels of the educational systems problems appear in regard to the teaching and learning of this subject. Perhaps this educational truth has increased the interest to undertake from different points of view studies that offer an alternative or guide to teaching and learning.

The following is a synthetic description of the most important aspects of an educational experiment in which it was realized concept mapping represents a teaching tool that is very useful within the process of the teaching and learning of mathematics. In particular it was observed that concept mapping are an important tool for the development of both cognitive and non-cognitive elements for students beginning their formation in mathematics in the field of engineering.

In the Autonomous Metropolitan University (UAM) of Mexico City two groups of students were selected: a control group and an experimental group, each with 30 students. Both groups were formed of students starting their initial formation in engineering. The control group has an ordinary course (traditional course) in the subject "Calculus I" and the experimental group had the same course following a process of teaching-learning supported by concept mapping. Both groups had a daily session for three months, taking into consideration the programming of the Autonomous Metropolitan University.

One of the relevant characteristics of this teaching research was that the teacher of the experimental group created a collection of concept mapping for the contents of the course "Calculus I" and used them as a guide for his teaching. The maps orientated him upon the way to present the information in order to promote the perception of information accessible to the students' intellect. The maps also contained graphic and visual information in order to support the mental representation and understanding of concepts. The teacher of the experimental group concentrated on putting into practice two elements of thought characteristics of logical reasoning: induction and deduction. Also put into practice were elements of thought proper to the capacity of spatial orientation: situating and locating in the line, in the Cartesian plane and in space.

Also during the sessions of the experimental group sub-groups were organized for team work under the very careful supervision of the teacher in each of the activities, mainly in the elaboration of concept mapping by the students. At each moment there was a horizontal relationship between the students and the teacher, promoting inductive and deductive thought processes, taking care of the appropriate level of exercises for each student, taking care in each sub-group of the correct construction of concept mapping, supporting the students with graphic and visual elements for the successful realization of exercises and problems. At every moment the doubts expressed by the students were resolved and an atmosphere of cordiality, confidence and respect among all of the participants of the experimental group was promoted.

To find out in what measure concept mapping used in the classroom contribute to the development of cognitive and non-cognitive elements, the following was carried out: for both the control group and the experimental group pre-tests were applied that measure Numerical Reasoning, Abstract Reasoning and Spatial Relationships (differential aptitude Test Dat-5). The test AF was also applied: Self-concept form 5 (García, F., & Musitu, G., 2001). Before initiating the training previous analyses were carried out (Student's **t**) which could check the two groups, both experimental and control group, were homogeneous in regard to Numerical Reasoning, Abstract Reasoning, Spatial Relationships and Self-concept, from the beginning. At the end of the course (training) post-tests were applied of the same instruments to all the students of both groups.

In this research the following hypotheses were maintained: If a group of university students (experimental group) receive a course of the subject "Calculus I" following a Teaching-Learning process backed by concept mapping and the results are compared with those of another group (control group) of similar characteristics who receive the same subject in a traditional form:

1. A noticeably superior increase can be observed in Numerical Reasoning – measured by Test "Dat-5" – in the members of the experimental group in regard to those of the control group.
2. A noticeably superior increase can be observed in Abstract Reasoning — measured by Test "Dat-5" – in the members of the experimental group in regard to those of the control group.
3. A noticeably superior increase can be observed in Spatial Relationships - measured by Test "Dat-5" – in the members of the experimental group in regard to those of the control group.
4. A noticeably superior increase can be observed in Self-concept – measured by Test "AF5: Self-concept form 5"—in the members of the experimental group in regard to those of the control group.

2.4 Results

To evaluate the differences in the results obtained between the pre-test phase and the post-test phase, between the experimental and control groups, an analysis was carried out of the results obtained, to which the following tests were applied: Student´s **t** (Parametric Test) and Assigned Ranks of Wilcoxon (Non- parametric Test). The results obtained permitted the verification of the truth of the hypotheses of the research. After processing the information from the Dat-5 measuring Numerical Reasoning for the two groups, statistically significant differences could be observed in the experimental group with a level of confidence of 99% between the pre and post test. Processing the information from Dat-5 measuring Abstract Reasoning and Spatial Relationships revealed significantly different statistics with a level of confidence of 99% between pre and post tests. Also, the processing of AF5 measuring Self-concept revealed significantly different statistics with a level of confidence of 95% between pre and post tests.

This affirms that there was a significant evolution in Numerical Reasoning, abstract Reasoning, Spatial Relationships and Self-concept in the experimental group. This increase is mainly explained by effect obtained by including in the teaching-learning process in a course of calculus, concept mapping as tools for the development of cognitive and non-cognitive elements

During the teaching experience there was an opportunity to obtain information from the students of a qualitative kind. Among the most important ideas collected are the following:

- Interest and tranquility are feelings expressed by the majority of students during the teacher's presentations and during the activities organized in the classroom. The students considered appropriate the presentation of specific information (examples), accessible to their intellect, supporting the introduction of concepts. They say that in this way they receive many elements to comprehend concepts and procedures to resolve problems. They say they feel comfortable and not stressed as when they do not follow the teacher.
- They rated favourably all the information received by electronic means (computer and projector) projected in images or graphic representations as an aid to comprehending theoretical aspects. Some students assured they had assimilated ideas and resolved successfully the exercises by relying on mental or graphic representations, referring to the well know phrase: in picture is worth a thousand words.
- The concept mapping prepared by the students themselves are important. They consider them back up documents for their personal study. The construction of the maps is attractive for them and it is rewarding to know the different ways to understand the concepts. They feel free to express their ideas without being afraid to be prejudged or disqualified. The students take the initiative trying to resolve exercises although they may come up against obstacles.
- The students consider it is important to know the concept mapping designed by the teacher. They feel this activity motivates them to construct their own maps with the contents of the course, thus developing their thought processes. They worry about comparing their own maps with those of the teacher.

- The students mention one of the important aspects of the course: they refer to the fact they have understood the theory and not memorized it. They consider they have made substantial learning advances. Some students state that certain concepts and procedures to resolve problems learnt in previous courses they still recall but without remembering the content: The why and wherefore. They feel the capacity to face up to calculus exercises that previously meant an unbeatable challenge.

3 Conclusions

One of the important aspects of this research is to be able to appreciate fully how concept mapping represent a useful tool to develop both elements of thought and elements of affectivity. One realizes that in the process of teaching and learning of contents proper to the field of the exact sciences, such as mathematics, the non-cognitive aspects are involved and the development of them is also important. It is very motivating for learning when the student experiences changes in regard to the concept he has of himself. The learning process is favourably affected when the students discover they have the capacity to solve mathematical problems that are apparently complicated. Naturally the research requires information of various stages of experimentation to continue constructing and refining statements that in their turn form the theoretical framework.

There are many ways to proceed in the classroom to achieve the learning of contents at the different educational levels. Using concept mapping as a guide for the teacher is a particular way to act. The teacher, by initiating the course with particular information and the support of graphic representations and images can get the concepts to generate in the classroom an atmosphere that favours mental activities in the students. They are not just passive observers, but from the beginning perceive, represent and conceptualize. Setting off the inductive and deductive processes implicit in mathematics develops intellectual performance: thought. By active participation in the classroom understanding the tasks carried out helps modify their attitude toward the contents and self-concept.

To carry out a teaching experience such as described here is a challenge. The activities to be designed must have a foundation in different ways to learn the contents. One may think that concept mapping are merely a different way to arrange or organize the contents. However, one must not lose sight of the fact that behind the concept mapping there is a theoretical body that sustains the idea. To include concept mapping as a teaching tool used by the teacher requires deep reflection on his part in regard to their immense potential. In this way teaching takes on special different aspects in relation to the traditional methods of proceeding in the classroom. The university requires new research into the processes of teaching and learning. Research to enrich pedagogical knowledge involving: students, teachers, contents and technology.

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Concept Mapping: Connecting Educators
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CONCEPT MAPPING IN SCIENCE EDUCATION ASSESSMENT: AN APPROACH TO COMPUTER-SUPPORTED ACHIEVEMENT TESTS IN AN INTERDISCIPLINARY HYPERMEDIA LEARNING ENVIRONMENT

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Abstract. The acquisition of conceptual knowledge is a central aim in science education. In this study, an interdisciplinary hypermedia-media assisted learning unit about hibernation and thermodynamics was developed and evaluated. But the assessment of interdisciplinary knowledge is not trivial. Therefore, concept mapping procedures were used to assess the cognitive effects within this complex knowledge domain. Learners constructed in a pre-post-test research design computer-supported concept maps, which were analysed with specific software. For data analysis, structural attributes and correspondence to a targeted reference map were used. The results showed higher-order domain-specific knowledge structures after the intervention, which indicate successful interdisciplinary learning with the hypermedia learning environment. In general, the benefit of computer-assisted concept mapping assessment for science education practice is discussed.

1 Introduction

1.1 Interdisciplinary Science Education and Hypermedia Learning

Science education deals with complex issues and requires multiple approaches for understanding. The acquisition of adequate conceptual knowledge implies the interconnection of scientific basic concepts and disciplines such as Biology and Physics. Subject-integrated approaches promote a learner's cross-linked ability (Ballstaedt, 1995) and that is why enrolment in interdisciplinary courses may lead to a more complex thinking process and improve reasoning abilities by problem-solving activities and inquiry tasks (Bünder, 2003). However, within interdisciplinary instruction and subject-integrated approaches learners always have to cope with complex objectives. Mammalian hibernation, for instance, is such an interdisciplinary learning challenge. The essential concepts of thermodynamics have to be applied to mammals' adaptation strategies to understand hibernation. But dealing with interdisciplinary topics implies a high cognitive load and should respect learners' needs as well as their preconcepts about thermodynamics.

In a stricter sense, one can understand interdisciplinary learning as the construction of a suitable and sustainable knowledge structure applying methodology and language from more than one discipline to examine a central topic (Jacobs, 1989). This knowledge structure consists of interconnected concepts (e.g. about thermodynamics) and provides a basis for conceptual understanding or meaningful learning. Meaningful learning occurs when individuals "choose to relate new knowledge to relevant concepts and propositions they already know" (Novak & Gowin, 1984, p. 7). Hypermedia learning environments help to construct knowledge within complex domains (Spiro et al., 1992). But hypermedia learning material ought to be adequately structured taking into consideration a learner's expertise, his/ her prior knowledge and computer-literacy as well (Weidenmann, 2001, Kerres, 2000). Within hypermedia learning environments learners have self-directed access to information units and can flexibly arrange their learning process in accordance with individual demands (Yildirim, Ozden & Aksu, 2001). Information is represented multimodal (visual & oral) and in multiple coding systems such as images, texts, text-/ image-combinations, graphs, tables, animations, films in order to be adequately mentally processed. Interactivity promotes a construction of active knowledge entities and reduces the danger of producing just inert knowledge (Schulmeister, 2002).
In this study, the focus is on the construction of conceptual knowledge about 'Life in Winter' and interrelated scientific concepts with an hypermedia learning environment for science education classroom (see detailed in Girwidz et al., 2006). Information about heat flow, energy transfer and hibernation of mammals is presented in a multifaceted learning environment fostering active knowledge acquisition. Two learners cooperatively work through information pages, animations, videos or simulations using an external workbook with a couple of sub-tasks. Far beyond simple memorizing or learning names of concepts, they gather knowledge with the real-life objective to finally "create" a virtual mammal for successful hibernation. The interrelation of biological aspects and thermodynamic fundamentals is exemplified at the beginning of every learning unit by a short video and has to be applied at this final task.

1.2 Concept Map Assessment

Interdisciplinary achievement and cumulative learning in complex knowledge domains are difficult to assess: Traditional test formats often tend to fail, especially when reading literacy or verbalisation skills require more effort than applying the actual states of knowledge (Goldsmith & Johnson, 1990, White & Gunstone, 1992). Therefore, concept mapping assessment may provide an alternative way to approach teaching as well as an additional method in educational research (e.g. Lin & Hu, 2003, Mitzes, Wandersee & Novak, 2001, Mc Clure, Sonak & Suen, 1999).

A consistent knowledge structure is essential for conceptual understanding, especially in complex and interdisciplinary knowledge domains. Thus, the interrelationship of concepts is seen as a fundamental attribute of knowledge. However, constructing concept maps needs to translate relevant cognitive structures into external networks which allow an interpretation of knowledge coherencies (Naveh-Benjamin & Lin, 1994). Concept maps can externalise an individual's recent standard of knowledge into a structured network of concepts, relationships or propositions (Novak, 1998). Consequently, changes of knowledge structures during an instruction can signal successful learning (Barney, Mintzes & Yen 2005, Engelbrecht et al., 2005, Yin et al., 2005, Stracke, 2004, Kinchin, 2001) and the validity and reliability of concept mapping assessment has been properly explored (Rye & Rubba, 2002, Ruiz-Primo et al., 2001, Martin, Mintzes & Clavijo, 2000, Mc Clure, Sonak & Suen 1999, Eckert 1998).

Nevertheless, scoring learners' concept maps for assessment is an often discussed issue and various methodological approaches are described in the literature. For instance, qualitative relational methods target the accuracy of each proposition; quantitative structural methods score the valid components in comparison to an expert- or criterion map (Gouli et al., 2005). Novak and Gowin's scoring method (1984) is used frequently as a basis of assessment. Ruiz-Primo's (2004) approach reflected a student's topic knowledge compared to an expert's structure with regard to an increasing expertise. Additionally, she distinguished concept maps by the different degrees of directedness (high-level directedness: Fill-in-the-Map; low-level directedness: Construct-a-Map without concepts provided) and pointed to three scoring systems: (1) of proposition accuracy, (2) of convergence with a criterion map and (3) of salience which is the "proportion of valid propositions out of all the propositions in the student's map" (Ruiz-Primo, 2000, p. 37). Ruiz-Primo and colleagues (2001) found correlations between this convergence score of construct-a-map procedures and learners' explanatory skills which gives evidence, that concept mapping assessment is "in fact measuring what is claimed" (p. 135). Mc Clure and colleagues (1999) compared holistic, relational and structural scoring methods without and with the use of a master map unveiling a high reliability for the latter. Thus, they recommend an assessment using master maps as compatible with science education practice.

The main objective of our study focussed on a concept map assessment within an interdisciplinary hypermedia-supported learning environment. We hypothesised that a learner's cooperative knowledge construction may lead to higher expertise in the specific domain of thermodynamics and hibernation. According to Bruhn and colleagues (2000) we chose dyads as empirical analyses' unity by focussing on the cooperative achievement and knowledge construction. The specific objectives of our present study were to monitor learners' skills and abilities in constructing integrated knowledge of mammalian hibernation strategies under biological and physical perspectives with the hypermedia environment. We used concept map scoring schemes which (i) score structural attributes and (ii) convergences with a criterion- or reference map.

2 Design and Procedures

2.1 Subjects and Intervention

Subjects were 9th graders at junior high schools (N = 106, age 15±1.2, medium stratification level, Realschule) working cooperatively in dyads (N = 53). The dyad formation itself was free of choice.

Each dyad worked with one notebook. The completion of a pre-test concept map with predetermined concepts and relations (T-1) included the monitoring of individual domain-specific prior knowledge and it became a part of the intervention itself. Pupils were guided through the hypermedia learning environment by an external workbook. Each dyad followed its appropriate individual working speed. The study program was completed within three days and consisted of six lessons. No further instruction or teacher support was provided. Immediately after the instruction the pupils completed a post-test concept map (T-2). For concept map assessment, a computer-software was used (MaNet® 1.6). All pupils were already familiar with this software; an assessment session in pre- and post-test was limited to 30 minutes each.

2.2 *Concept Mapping Assessment with MaNet® 1.6*

For analysis we used the software MaNet® (MaResCom, 2006) which allows a learner to construct concept maps intuitively on-screen, either with or without given concepts and relations. Furthermore, it allows a researcher to apply different automated scoring schemes. For our present study, predetermined concepts (eg. "a high temperature difference") had to be connected with a set of specific and directed relations (eg. "…leads to…"). Monitoring learners' interdisciplinary achievement needs a multidimensional assessment. Hence, differentiated analyses consider both structural attributes and correspondences with a reference map.

2.2.1 Scoring structural attributes

Scoring the concept maps by structural features before and after an intervention allows drawing conclusions about general achievement (see detailed in Eckert, 1998, Stracke, 2004). For our present study, the relevant structural attributes were (i) the 'volume' of a concept map (≙ total number of relations used in the learners' concept map), (ii) the 'ruggedness' which is the division of a concept map into un-connected sub-maps (Bonato, 1990) as well as (iii) the amount of accurate propositions in relation to the volume.

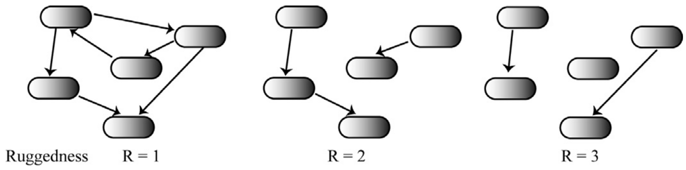

Figure 1. Ruggedness of a concept map

We followed the underlying theoretical assumption that an increase in knowledge structures' quality is related to a higher-order cross-linking between relevant concepts: Thus, a low ruggedness is considered as an indicator for a consistent knowledge structure (Bonato, 1990). However, a successful achievement might be imprecisely detailed since decreasing ruggedness or increasing volume do not allow any concrete conclusion about the concepts' appropriateness. As concept mapping assessment in this present study emphasizes more differentiated research questions, other scoring methods should be applied using a criterion- or reference map based on the intended learning target.

2.2.2 Scoring correspondence to a reference map

Corresponding a learner's concept map with an expert's one is regarded as a valid and reliable scoring method (Stracke, 2004, McClure et al., 1999). Thus, the construction of a reliable reference map is the first important aspect. Therefore, a procedure respecting Stracke's (2004), Ruiz-Primo's (2000) and Rye & Rubba's (2002) findings was used by integrating learning target oriented approaches to construct a list of interdisciplinary key-concepts and relations:

1. Analysis of learning target	Researcher group consisting of three experienced teachers (biology, mathematics & physics) and two university professors (biology and physics) declared the most important achievement goals to understand the hibernation phenomenon.
2. Definition and selection of essential propositions	Each group member provides a list of most central propositions (concepts linked by labelled relations) in the domain of thermodynamics (eg. "<u>great body surface</u> increases <u>the energy transfer by conduction</u>"). Then, a list of key-concepts and relations is created.
3. Construction of a reference map	The research group cooperatively constructs a common reference map with the concept- and relation-list.
4. Experts' individual concept map	Four other autonomous university teachers and professors (three biology and one physics) constructed an individual concept map using the provided concepts and links.
5. Validation of the reference map	The research group expert map and the average map of the four the autonomous experts are compared. The reference map showed an accordance of 89 %.
6. Using the research group map as reference- or criterion map	

Table 1. Adapted procedure for criterion map construction (Schaal, 2006).

In this study, each assessment concept map included a total of nineteen concepts and six labelled relations. A coefficient of correspondence, which is calculated based on an inter-relational matrix, allows a comparison of a learner's concept map to the reference map (Eckert 1998, 2000):
Two concepts are …

in the learner's map		*in the expert map*	*label*
not connected	and also	not connected	cnc (correctly not connected)
not connected	but	connected	mc (missing connection)
connected	but	not connected	wc (wrong connection)
connected	and also	connected	cc (correct connection)

Table 2. Matrix of interrelations within a concept map

The coefficient of correspondence C is calculated by the formula

$$C_w = \frac{\sum cnc + \sum cc - \left(\sum mc + \sum wc\right)}{\text{maximal amount of interconnections possible}}$$

The value of this coefficient is between -1 and 1. The value -1 means an absolute negative of the reference map and the value 1 is consequently the result, if a learner's map is identical to the reference map. The coefficient of 0 is reached if there are as many wrong/ missing connections as correct connections/ correctly not connected links. The coefficient of correspondence is computed automatically with the MaNet® software in comparison to the reference map.

The similarity or correspondence to a reference map can be assigned to different criteria of increasing rigour:

- a link is considered as undirected and unlabeled (C_1). Every accurate link between two or more concepts is considered as valid,
- a link is considered as undirected, but labelled correctly (C_2). Links are counted, if the label is accurate,
- a link is considered as directed and labelled correctly (C_3). Links are only counted, if the direction and the label are accurate.

In addition to an 'ordinary' correspondence the comparison of two concept maps can also be conducted considering a kind of weighted procedure: For instance, an accurate proposition in a rarely linked concept map scores higher than a proposition in one with a high volume. Therefore, a weighted coefficient of correspondence (C_w) should be used. The weighting factor W is defined as

$$W_1 = \frac{\sum \text{correctly connected in reference map}}{\sum \text{correctly not - connected in reference map}} \text{ and } W_2 = \frac{1}{W_1}.$$

As a consequence, the formula for the calculation of the weighted coefficient of correspondence is modified:

$$C_w = \frac{W_1 \cdot \sum cnc + W_2 \cdot \sum cc - \left(W_1 \cdot \sum mc + W_2 \cdot \sum wc\right)}{\text{maximal amount of interconnections possible}}$$

The values of the C_w are also between -1 and +1, in general they are lower than the unweighted ones. Thus, the comparison of two concept maps with the weighted coefficient of correspondence can be considered as more rigorous than the unweighted one (Stracke, 2004). Therefore, in this study only the weighted coefficients are used for empirical evaluation.

3 Results

Two main hypotheses were tested:

(i) The structural attributes of a learner's concept map score higher after cooperative working with our hypermedia learning environment.
(ii) A learner's concept map increasingly adjusts to an expert's domain structure.

As some variables were not normally distributed (Kolmogorov-Smirnov: pretest: Volume $U = 1.49$, $p < .05$; ruggedness $Z = 1.85$, $p < .01$. C_2 $Z = 1,.57$, $p < .05$; posttest: C_{2w} $Z = 1.55$, $p < .05$), we applied non-parametric procedures (*cf.* Bortz & Döring, 2002).

3.1 Achievement- structural attributes

In general, post-test concept maps showed a higher consistency and interconnectedness compared to pre-test. Structural attributes strongly differed before and after the intervention: the number of relations in the post-test increased while the ruggedness of learners' concept maps decreased. The concept maps emerged from a status of separated submaps towards a more consistent pattern. Both its volume and the amount of accurate propositions also increased (Fig. 2).

N = 53	R+	R-	Z	Sig.(2-tailed)
Volume	24.1	48.1	-4.8	p < .001
Ruggedness	37.7	15.8	-5.2	p < .005
Accurate propositions	0.0	47.5	-8.7	p < .005

Table 3. Paired-sample Wilcoxon-test for structural attributes in pre- and post-test.

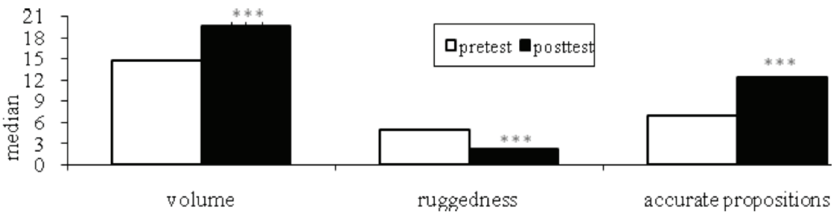

Figure 2. Achievement according to structural attributes (*** = p < .001; 2-tailed) (N=53)

The quotient score of accurate propositions relative to the volume also increased from pre- to post-test (Wilcoxon: Z = -6,91; p < .001). Therefore, the first hypothesis (i) concerning the increase of structural attributes through cooperative working with the hypermedia learning environment has to be accepted.

3.2 Achievement – analysis of correspondence

For further analysis of a learner's concept map relationship with reference maps, weighted procedures were introduced. These procedures are considered to assess content-oriented relational correspondence objectively (Stracke, 2004).

	pre-test		***post-test***	
	Median	*SD*	*Median*	*SD*
simple correspondence C_{1w}	-0,30	*0,12*	-0,15	0,14
medium correspondence C_{2w}	-0,42	*0,11*	-0,30	0,17
rigorous correspondence C_{3w}	-0,45	*0,10*	-0,32	0,15

Table 4. Medians of coefficients of correspondence (N = 53).

The coefficients of correspondence showed increasing achievement from pre- to post-test: Figure 3 indicates the increase pattern ($C_{1\text{-}3w}$). As expected, the C_{3w}-values scored lowest.

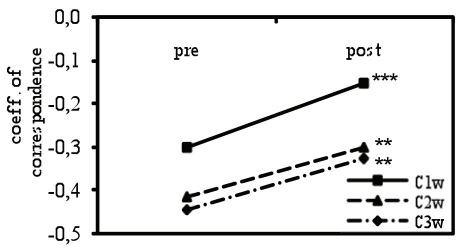

Figure 3. Increase of correspondence from pre- to post-test
(** = p < .005; *** = p < .001; two-tailed significance)

N = 53	R+	R-	Z	Sig.(2-tailed)
simple correspondence C_{1w}	17.7	30.9	-4.2	p < .001
Medium correspondence C_{2w}	22.6	22.6	-3.1	p < .005
rigorous correspondence C_{3w}	22.4	29.0	-3.2	p < .005

Table 5. Paired-sample Wilcoxon-test for coefficient of correspondence in pre- and post-test.

A learner's concept map matches closer the reference map due to instruction. Thus, the second hypothesis (ii) has to be confirmed. This increase of correspondence is proportional to at least three to five additional central propositions (each consisting of at least two concepts and a relation) from pre- to post-test.

4 Discussion

Concept mapping offers a suitable method for assessing important learning effects within classrooms. Learners' concept maps became more consistent, more elaborated and showed more appropriate linkages between the miscellaneous concepts after the learning unit in this study. In general, the maps improved, getting a higher similarity with an expert's reference map respecting interdisciplinary cross-linking. Thus, learners developed adequate structural knowledge about hibernation from pre- to post-test. Consistently with previous studies the complexity of the knowledge structures also increased (c.f. Barney, Mintzes & Yen, 2005; Engelbrecht et al., 2005). In summary, our hypermedia learning environment supported the construction of an interdisciplinary knowledge structure based on interrelated concepts of biology and thermodynamics. Due to the enduring lack of empirical achievement data in interdisciplinary learning settings (e.g. Stevens et al., 2005) we consider this finding to be important.

Concerning the hypermedia learning environment, pupils solved problems cooperatively on their own and they had to overcome various learning obstacles. Obviously they performed quite well during the computer-supported lessons and could adequately accomplish a self-determined learning approach. These results are in line with previous studies. For instance, Yildirim and colleagues (2001) compared traditional media and hypermedia environments regarding knowledge acquisition and retention effects and revealed this as an appropriate basis to acquire sufficient knowledge. The time-consuming instruction of biological and physical basic concepts, in our case of hibernation, can be shortened and thus, the time for experimental and problem-solving hands-on activities increases. Klahr, Triona and Williams (2006), for instance, compared the educational effectiveness of virtual versus physical materials; they described virtual learning materials as producing similar gains with regard to acquired knowledge and student's self-confidence. Thus, virtual learning material can additionally attribute to knowledge improvement, but, of course, cannot substitute the very specific advantage of hands-on activities. Nevertheless, it provides a very helpful tool to supplement other approaches. Even so, when arrangements about conceptual knowledge are enforced (as in the present study) comparable prior knowledge seems to be important for joint interaction and becomes a relevant factor for learning. This aspect might be measured by traditional school grades which will be presented more detailed in Schaal and colleagues (2008).

Our learner's dyads constructed their concept maps very quickly and efficiently by using the computer-based concept mapping program. The computer assisted empirical analysis of learners' concept maps clearly showed learning effects and allowed a direct interpretation. Paper-and-pencil concept mapping often has to cope with practical problems like, for instance, irreversibility of drawn proposition, difficulties with erasing or adding concepts and relations in a pre-existing map, 'translation'- or interpretation-errors. However, constructing concept maps on-screen was efficient and very intuitive for our learners. Furthermore, a comparison of concept map data used in this study and the data of the former study mentioned above (Girwidz et al., 2006) showed similar tendencies in individual learning, but also further ongoing aspects about knowledge structures. Consistent results about retention and conceptual knowledge were found, indicating a sufficient validity of the procedure for those aspects. However, most important is the innovative possibility to get insights into structural aspects of our learners' knowledge and linkage of concepts. Nevertheless, concept map assessment still is not a common tool in the scientific community and more experience is needed.

5 Outlook and consequences

This study shows the potential of a specific interdisciplinary approach providing adequate interconnected knowledge about a specific topic by using hypermedia. This might be also true for other interdisciplinary domains in science education, for example, the visual perception (c.f. Schaal & Bogner, 2005), or biotechnology. Interactive and self-determined computer-supported learning settings can perform more authentic problem-based learning scenarios. A hypermedia learning environment allows interactive manipulation of virtual objects, e. g. lenses, animals' eyes and optical illusions. In contrast to that, traditional media or audio-visual media can hardly overcome passive learning (Berck, 2005). Although our interpretation is still tentative and needs further research, other computer-based learning studies point into this direction, too.

It is a question whether learners of middle-stratification can cope with both demands, the interdisciplinary science education and the hypermedia learning at the same time. Nevertheless, the application of computer-assisted concept map assessment is an easy, time-sensible and reliable approach, offering supplementary and substantial innovations to conventional paper-and-pencil tests. Science educators in every-day classrooms can easily assess an achievement by using concept maps. Comparing reference maps with individual maps of students may even become a learning target. Thus, a computer-supported concept mapping may profit every-day courses.

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CONCEPT MAPPING, VEE HEURISTICS AND THE LEARNING PROCESS: TOWARDS A META-LEARNING EXPERIENCE

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Abstract. For too many years, teachers have prepared lesson plans according to their own preferred way of learning whilst ignoring the fact that all children process incoming information differently and in this way, many children are left behind. If one wants to be successful one must understand how one learns and then make sense of it so as to make one's mental mechanisms work most efficiently for him/her. This paper will describe that when Vee Heuristic and Concept Maps are placed within a context of an understanding of different learning patterns, the learning process develops from a metacognitive level to a meta-learning experience thereby equipping the learner with a life-long learning skill.

1 Introduction and Background information

Education is of highest priority to every nation around the world. Education can be defined as "the organised, systematic effort to foster learning, to establish the conditions, and to provide the activities through which learning can occur" (Bruner, J. 1971:35). Furthermore, Wilson argues that "to be interested in education is to view him (the child) primarily as a learner" (Wilson, J. 1975:44). However, for too many years, teachers have prepared lesson plans according to their own preferred way of learning whilst ignoring the fact that all children process incoming information differently. Similarly, Novak argues that teachers tend to "focus on teaching activities and tend to ignore learning activities. They center attention on how to teach a given topic, rather than on what is required for a learner to learn the topic. This stems, in part, from teachers' limited knowledge of the learning process" Novak, 1998:120). In this way, many children are left behind or build an image of themselves as non-learners. Yet, everyone can learn!

But when and how does learning occur? What do we mean by the word 'learning'? 'Learning' is one of those words everyone uses, and seems to understand, but would be hard pressed to define. Learning is a complex process involving different mental processes. We have all experienced it, we usually know it when we see it and we tend to accept its crucial function in life. Understandings of learning have advanced significantly in the past few decades and increasing attention has been given to 'higher order' processes of understanding. Consequently, the term 'metacognition' (awareness of thinking processes/thinking about thinking) has become the latest buzz word in educational settings. Indeed learning is an integral part of our being and as such, it cannot be overlooked. If one wants to be successful one must understand how one learns and then make sense of it so as to make one's mental mechanisms work most efficiently for him/her. This is the primary reason why educational research is nowadays focusing on meta-learning (learning about learning). "*Meta-learning covers a much wider range of issues than metacognition, including goals, feelings, social relations and context of learning*" (Watkins, 2001:1). Meta-learning is to make sense of one's own experience of learning and in this way the learners would be equipped with a life-long learning skill.

This research made use of Vee Heuristics and Concept Mapping as effective metacognitive tools (Novak, 1984,1998; Cañas et al, 2004, 2006) and so as to provide a metacognitive understanding to our learners and to the teacher, this research made use of the Learning Connections Inventory (LCI) which is an instrument developed by Johnston and Dainton to profile an individual's learning patterns. The theoretical basis for the LCI is the Interactive Learning Model, which posits that learning processes occur through the interaction of three mental processes: Cognition (I think), Affectation (I feel) and Conation (I act). Each of these components is taken into consideration and through their interaction; learning patterns are formed and each pattern is distinguished by a number of features. A few characteristics are listed below:

Sequence	learners prefer order and consistency. They like to follow step-by-step directions, and time to plan, organize and complete tasks.
Precise	learners who thrive on detailed and accurate information. They take copious notes and seek specific answers.
Technical Reasoning	learners who like to work alone on hands-on projects. They enjoy figuring out how something works and enjoy doing tasks which is relevant to their lives.
Confluence	learners who have a strong desire for creativity and innovation. They are not afraid of risks or failure and prefer to be unique or unconventional approaches.

Table 1: different characteristics typical in different learning patterns (Johnston, 2005)

The Let Me Learn Process® is truly an advanced learning system since unlike other learning styles it doesn't place the learner into one single quadrant but reveals that the patterns are ***all*** used by ***all*** learners but to varying degrees. A learner's LCI reveals the learner's profile by determining the strengths of his/her preferences and avoidances scored as "avoid", "use as needed" and the "use first". Therefore, some learners lead with one or two patterns, some avoid certain patterns, some are able to use a number of patterns on an as-needed basis and still others exhibit strong preferences for a number of patterns.

	How I think	How I do things	How I feel	What I might say
Sequential Process	▪ I organize information ▪ I mentally analyze data ▪ I break tasks down into steps	▪ I make lists ▪ I organize ▪ I plan first, then act	▪ I thrive on consistency and dependability ▪ I need things to be tidy and organized	▪ Could I see an example? ▪ I need more time to double-check my work ▪ Could we review those directions?
Precise Process	▪ I research information ▪ I ask lots of questions ▪ I always want to know more	▪ I challenge statements and ideas that I doubt ▪ I prove I am right	▪ I thrive on knowledge ▪ I feel good when I am correct	▪ I need more information ▪ Let me write up the answer to that ▪ Did you know that….
Technical Process	▪ I seek concrete relevance – what does this mean in the real world? ▪ I only want as much information as I need	▪ I get my hands on ▪ I tinker ▪ I solve the problem ▪ I do	▪ I enjoy knowing how things work ▪ I need real world relevance ▪ I do not need to share my knowledge	▪ I can do it myself ▪ Let me show you how… ▪ How will I ever use this in the real world? ▪ I could use a little space…
Confluent Process	▪ I read between the lines ▪ I think outside the box ▪ I brainstorm ▪ I make obscure connections	▪ I take risks ▪ I am not afraid to fail ▪ I talk about things – a lot ▪ I might start things and not finish them	▪ I enjoy energy ▪ I feel comfortable with failure ▪ I feel frustrated by people who are not open to new ideas	▪ What do you mean, "that's the way we've always done it"?! ▪ The rules don't apply to me ▪ I have an idea…….

Table 2: These patterns represent how the learner sees the world, takes in stimuli, integrates the stimuli and formulates a response to it. (Johnston, 2005)

2 Methodology

This paper will describe that when Vee Heuristics and Concept Mapping are placed within a context of an understanding of different learning patterns, the learning process develops from a metacognitive level to a meta-learning experience.

In this research I used Vee Heuristics and Concept Mapping in a primary classroom so as to improve on meaningful learning of a specific environmental issue related to biodiversity. Since the Vee Heuristic presented in Novak & Gowin (1984) was too complex to tackle with six to seven year old, I opted to adapt the wordings as presented in Ahoranta's adapted version of Åhlberg's improved Vee Heuristics which have withstood theoretical and empirical testing from 1993 to 2006 and have been applied to Environmental Education in Finland for several years (Åhlberg in Cañas et al 2004; Åhlberg & Ahoranta, 2002; Åhlberg & Ahoranta in Cañas et al 2004).

Furthermore, a semi-structured interview was carried out with a number of selected different types of learners so as to find out the details of the children's knowledge and maybe even misconceptions of the environmental issue in discussion through a Concept Map constructed **before** the learning project and how this knowledge was developed to construct new meaningful knowledge in a second Concept Map constructed **after** the learning project. Finally, the different learners' learning patterns were taken into consideration as to how or whether they contributed to diverse structures of knowledge.

3 Data Analysis

I shall now present, analyze and discuss in detail this process with two learners having different learning profiles. This is only just a very small part of a larger research results published as a Masters in Education Theses for the University of Malta.

3.1 Nina: Her LCI score was Sequence 23; Precision 22; Technical 23; Confluence 19 (7-17= Avoid; 18-24=Use as Needed; 25-35=Use First).

The LCI score of Nina represents a ‘bridge learner’ (Johnston, 2005) since she avoids no learning patterns nor does she make use of any at a Use First Level. This means that this learner enjoys learning through many ways, through listening and interacting with others and she feels comfortable using all of the learning patterns. She finds it easy to adapt to different situations and so she can blend in and help make things happen as a contributing member in a group. This kind of learner weighs things in the balance before she acts and the following Vee further confirms how Bridge learners process incoming information.

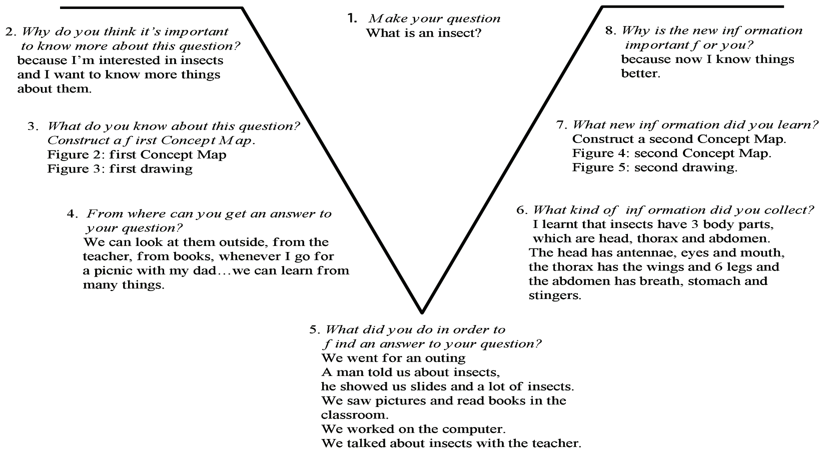

Figure 1: Nina’s Vee Heuristic

From this Vee Heuristic one can easily note that Nina is able to learn in various different situations. The first reply shows her interest since she’s a kind of learner who is interested in many things that surround her and that she’s interested in expanding her prior knowledge. In reply no.4 we have a very clear picture of how Nina would like to learn and this substantiates her LCI score since she mentions various ways both inside and outside the classroom setting. Her learning patterns are further reinforced in reply no.5 where one can note the emphasis she puts on learning through interacting and listening to other people since she mentioned both the teacher present in the classroom context and a man present in an outside the classroom context. The reply in No.6 is quite detailed, very confident and straight forward revealing how much she felt good with the new knowledge learnt. It is worth noting that Nina found the information useful because now she knows “*things better*” suggesting this learner’s motivation and willingness to improve on what she already knows.

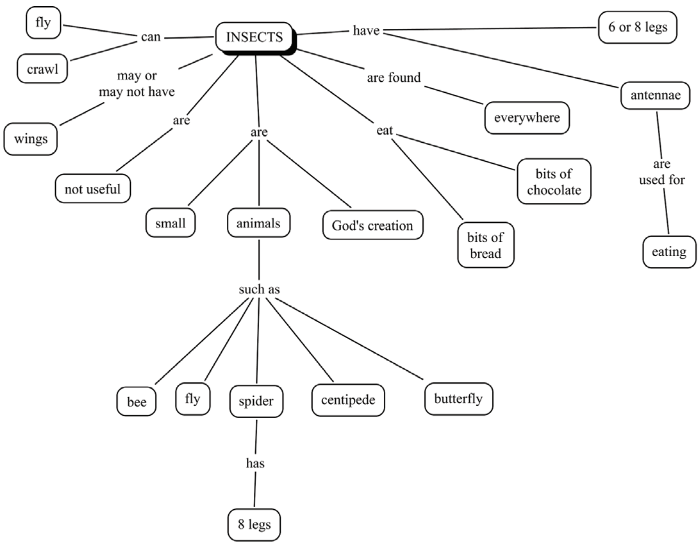

Figure 2: Nina’s first Concept Map before the learning project.

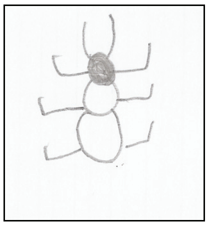

Figure 3: Nina’s first drawing before the learning project

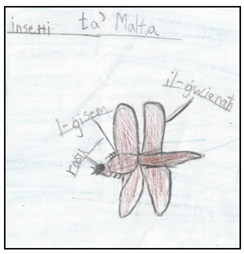

Figure 5: Nina’s second drawing after the learning project.

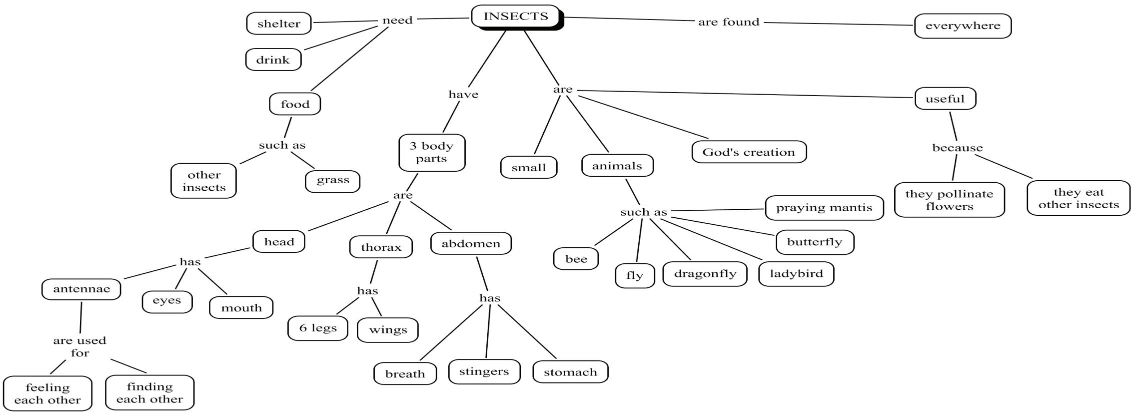

Figure 4: Nina's second Concept Map after the learning project.

When comparing the two Concept Maps presented in Figures 3 and 4, one can observe that learning has taken place due to the increase in the number of concepts and propositions. From the first Concept Map one can note a good number of correct concepts and this is substantiated in her first drawing in Figure 5. From Nina's first drawing one can also remark on the three visible body parts, however this is not represented in the first Concept Map. This could be because this concept was caught by Nina's observational skills since she learns in different situations but it was never externalised or developed. In the second Concept Map, however, one can observe how well Nina refined her knowledge about insects by correcting all her previous misconceptions while extending other good concepts. If we take a closer look at the second drawing, we can note how well refined it is even with regards to the proportion of the size of the three parts of the body. One can see that while in the first drawing each part of the body held a pair of legs, the second drawing depicts the legs coming out from the thorax.

3.2 Anna: Her LCI score was Sequence 23; Precision 27; Technical 20; Confluence 15 (7-17= Avoid; 18-24=Use as Needed; 25-35=Use First).

Anna is a dynamic learner (Johnston, 2005) who scores high in Precise therefore she feels the need to be accurate and correct when answering questions and she attends to details. She prefers to express herself in words but she needs complete and thorough explanations. She avoids Confluence so she would rather NOT make mistakes than having to learn from them, besides she's more cautious in how she's going to answer questions and she does not like to take risks. There are only certain aspects that she uses from her Sequential and Technical patterns since her scale score of these patterns falls in the Use As Needed.

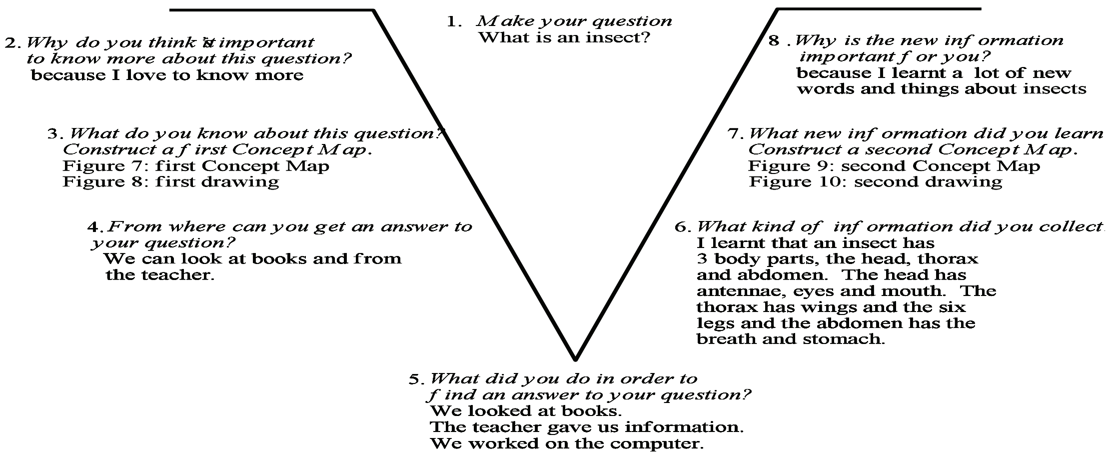

Figure 5: Anna's Vee Heuristic

This Vee Heuristic once again reveals this learner's preferred way of processing incoming information. In reply No.2, from the use of the phrase "*I love to know more*" one can see that this girl enjoys learning and developing her knowledge. Scoring high in Precise means that one wants to get more and more information and is motivated by lots of details. In reply No. 4 the learner sheds light upon how and from where she prefers to get the necessary information. She didn't mention observation, imagination or going out from the class to have hands-on learning but instead she mentioned "*from the books and from the teacher*".

This is substantiated in reply No. 5 where one can note that the primary sources of her learning were actually the books and the teacher. In fact, during the interview this was her instant reply and only when I prompted "*anything else*?", did she mention the computer. Once again the answer to question No. 6 has a lot of exact details and in reply No. 8 one can become aware why this new information was important for this learner, "*because I learnt a lot of new words*". Here again we see how important words are for this learner.

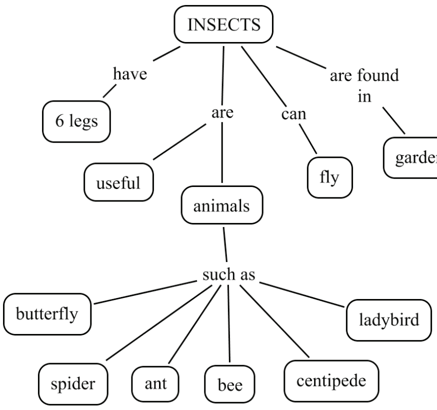

Figure 7: Anna's first Concept Map before the learning project.

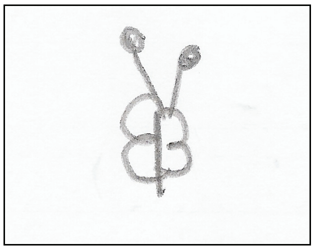

Figure 8: Anna's first drawing before the learning project

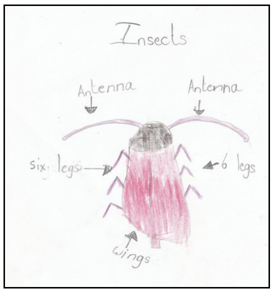

Figure 10: Anna's second drawing after the learning project

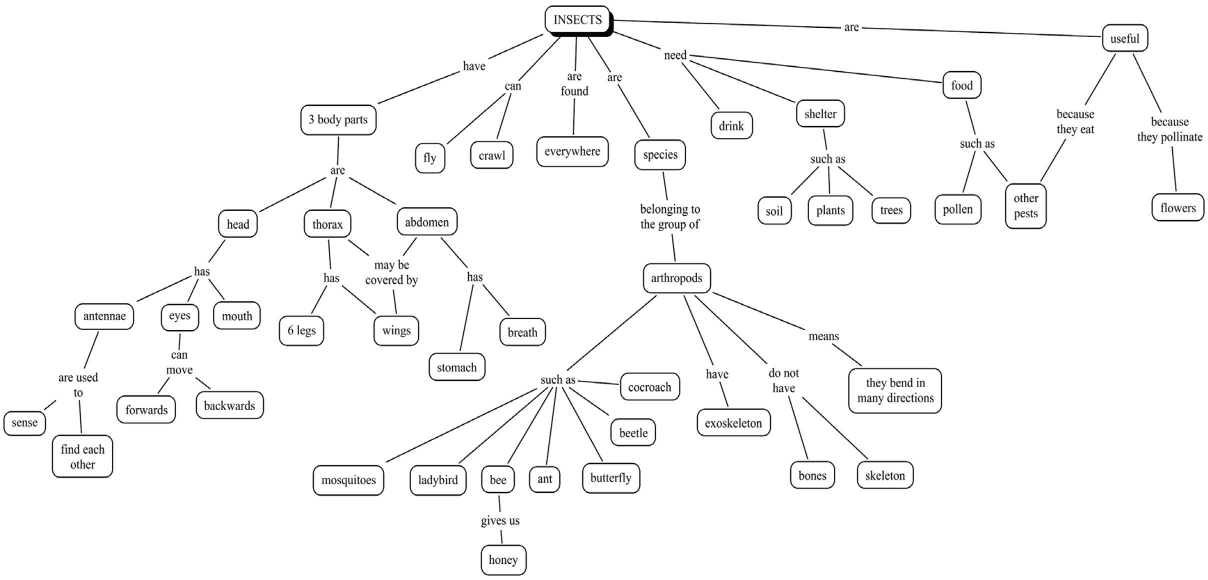

Figure 9: Anna's second Concept Map after the learning project

When we take a look at the two Concept Maps presented in Figures 7 and 9, we can note an impressive increase in concepts and propositions and this implies that learning has taken place. Even here, this learner was able to delete the misconceptions and expand her concepts. In the first concept map (Figure 7) one can observe that there are almost no misconceptions except for the concepts that a spider and a centipede are insects. If we refer back to this learner's learning patterns we can understand that her high score in Precision keeps this learner from taking risks, she has to take time to think and she prefers not answering than risking to answer incorrectly. This is why her first Concept Map, though limited, contains a lot of good concepts. These learning characteristics were also exhibited during the interview. It is also worth remarking that she was the only learner in this study to know exactly how many legs an insect has and she stated that she knew this "*because I saw a picture in a book and I counted how many legs it has*". She was also the only one to be convinced that insects are useful but at this stage she was unable or in this case, uncertain how to explain it.

If we closely observe her second Concept Map (Figure 9), we find out that it's amazing how this girl was able to go into details. I am referring to the details such as *"the eyes can move forwards and backwards"* or that *"the thorax and abdomen may be covered by the wings"*. She not only increased the number in concepts and propositions but she also extended by giving reasons or examples. It is worth noting the correct use of detailed words such as "*pests*", "*arthropods*", "*exoskeleton*" and "*species*" and these are further proof of what a learner who scores high in Precision enjoys learning most. When constructing the second Concept Map, this girl needed prompting to carry on; she needed reassurance that what she was doing was correct. When she was first asked to draw an insect she was quite reluctant, stating *"but I don't know how to draw",* she drew the insect only after feeling safe on listening to what I had to tell her, hence *"don't worry, you can draw it how you like, it's just going to help us learn something more about insects"*. The second drawing carried out after the project was done with more confidence and labelled very well with distinct parts of the body whilst also having number 6 written in numerical form on one side and in letter form on the other.

4 Discussion

The data collected in this research reveals that each learner processes and responds to incoming information in various distinctive ways. Nonetheless all of the learners were able to construct new knowledge when presented with a learning programme which suited their preferred way of learning and when being actively involved in their own learning. This is where I found the Let Me Learn Process most valuable since it revealed how each learner prefers to learn and how and why she/he responds to incoming information in the way they do.

4.1 Vee Heuristics

Very often learning starts off with a question and actually the `focus question` is placed at the top centre of the Vee since questions "*are what drive the inquiry that leads eventually to new knowledge*" (Novak, 1998:85). Eliciting a focus question from the children proved to be more challenging than I had anticipated. I found out that by already the age of six, children are very often conditioned to become passive learners and so are not trained to reflect and question critically. "*In many ways, the reason for this anomaly lies in the nature of both society and the primary classroom*" (Johnston, 1996a:33) There are various reasons why children find it difficult to raise questions and this is analyzed and discussed in detail in my complete research. However, I can say that the key to developing the skill of raising questions is to create an atmosphere in the classroom where the children feel safe in practicing this skill. Actually, I had to do several various activities (figures 11, 12 & 13) revolving around this notion before I could elicit a focus question. Similarly Cañas & Novak (2006) argue that "*one of the difficulties that seem to be pervasive is the lack of a (good) focus question that focuses the construction of the Concept Map*" (Cañas & Novak, 2006:494). Through this research I found out that this is the product of the prevailing transmission model which many schools still advocate where children are told to "sit down and be quiet".

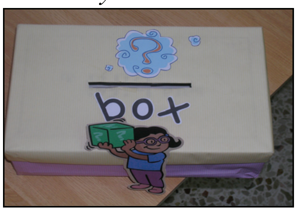

Figure 11: A question box

Figure 13: Display of question words.

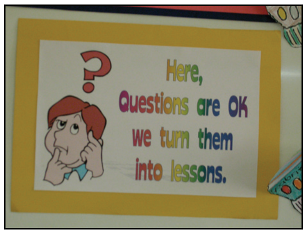

Figure 12: *Here, questions are OK, we turn them into lessons.*

Focus questions lead the learner to trigger off a process of reflection and so are a key step in the whole process since the teacher has to stop and consider the children's questions. Many teachers tend to ignore young children's questions or else they are very disposed to provide a quick answer thus inhibiting the learner from going through a process of higher order thinking skills, problem-solving and decision making skills. Also, research shows that teachers tend to become more didactic and switch on the transmission mode, the less they know about a subject (Frost, 1997).

The left hand side of the Vee is the thinking part of the whole process, where one is encouraged to stop and reflect upon what one already knows about the focus question. It also reveals one's relation to the question and why he/she wants to know more about this question and therefore, emotions are here highlighted. Many teachers have the syllabus and they have to deliver it and very rarely do they stop to consider how the child feels about what he/she is learning. Very often, teachers tend to take for granted that children come to class all prepared and ready to take in the information we present to them. This is a very important factor to consider since it will directly affect learning. Too often teachers get subsumed in their daily fast routine of lessons where the content becomes more important than the process so missing out on other major elements occurring in the learning process. As Novak argues "*the complex interaction that takes place between stored information about knowledge, feelings and actions is very important in education*" (Novak, 1998:25). A lesson might be very well prepared but it is done so according to the teacher's own knowledge and experiences and many times it ignores the learner's prior knowledge and experiences and in this way learning becomes superficial.

This side of the Vee is also very effective in capturing how the learner plans to learn. From the data collected we can observe the diverse ways in which learners plan to learn, there are those who plan to ask the teacher or by referring to books or through hands-on experience or even through imagination, observation and in their daily lives. So this part of the Vee helps the teacher to plan a learning programme which suits the different learners' preferred way of learning thus increasing relevance and motivation.

The right hand side of the Vee focuses on our action, what we did so as to develop our knowledge and what new knowledge was constructed. Novak (1998) reveals that the shape of a Vee was chosen above other shapes because one can clearly distinguish that both thinking and doing are implicated in the process of learning. The learners presented in this study reveal that while certain learners learnt well in a classroom setting, others preferred an outside the classroom setting. This side of the Vee also sheds light upon why the new knowledge constructed was important for the learner. It was very clear that all learners in this study presented different feelings, while some were happy to be able to learn new words, new information (like Anna) others were happy because they could comfortably and visually communicate what they had learned (like Nina).

4.2 Concept Maps

From the Vees presented in figures 1 and 7 in their simplest form possible, one can easily note that within the whole process there is the construction of a first Concept Map prior the whole process and the construction of a second Concept Map at the end of the whole process. From the comparison of these two Concept Maps, both the teacher and the learner can observe how their knowledge was constructed and developed. This is yet another key step in this whole process since it responds to Cañas & Novak (2006) concept map-centered environment proposition where "*the concept map evolves from an intial `assessment` of what students know about the topic being studied to a knowledge model reflecting the students' progress*" (Cañas & Novak, 2006:501). The data analysis presented evidences that through Concept Mapping, misconceptions were detected and altered while missing gaps of information were included and this is an ongoing process as learning continues, revealing that learning is continuous and never ending.

The cognitive structures represented in this way makes it relatively easy to follow the development of new knowledge and the specific changes in the learners' knowledge structure since Concept Maps give a specific picture of what the child has in her/his head (Kinchin, Hay & Adams, 2000, Cañas et al, 2004, 2006). The first Concept Map is very important since it exposes what the learner has in his/her head about the issue under study and in this way the teacher can pin-point any misconceptions or missing information so as to build his/her instruction accordingly. According to Vygotsky this is where learning occurs and he terms this as the Zone of Proximal Development (ZDP). Ample research has shown that new meaningful knowledge does not occur in a vacuum (Bruer, 1993; Johnston, 1998; Novak, 1998) and so prior knowledge has to be taken into consideration if we expect meaningful learning to take place. Through the data analysis I could observe that Concept Mapping helped those learners, who tend to answer quickly without reflecting, to organize more their thoughts since when they were revisiting their first Concept Map, they could visually see where the concepts were missing or where relationships were not appropriate and therefore they inserted the necessary information or relationships and in this way retention will automatically follow (Kinchin, Hay & Adams, 2000).

4.3 The Let Me Learn Process

My prior knowledge of the Let Me Learn Process was crucial in this whole process since it facilitated my understanding of how learners will apply their thinking processes presented on both sides of the Vee in order to learn more effectively since it revealed how both, the student and the teacher, made their learning mechanisms work most efficiently for them. With an awareness of the diverse children's learning patterns I could make this whole process make more sense to the learners and so I was in a much better position to negotiate meanings and experiences in a way which was meaningful for the learners. With such awareness teachers and students may form partnerships based upon the knowledge of each other's ways of processing incoming information and they are able to create an atmosphere in which they have the opportunity to formulate specific techniques and strategies for developing learning that makes sense to them (Johnston & Johnston, 1997).

5 Conclusion

By going through the whole process of the Vee Heuristic, it is very unlikely to disregard relevant key concepts or information, moreover, ideas are, in this way, more organized. In this way, teachers are made to stop and consider what the learner's question is, what the learner's prior knowledge and feelings are about the issue in question. The teacher is also made to reflect on the learner's preferred way of learning so as to adjust to the learner's needs in order to be able to learn meaningfully. Moreover, this whole process is negotiated with the teacher, therefore it cannot be ignored by the teacher while empowering the learner to become an active agent in his/her own learning process. This teacher/learner negotiation lead to what Novak calls 'emotional sensitivity', that is, during this process the teacher can perceive what the emotional status of the learner is whilst also becoming aware of her/his own emotional status and this has a direct affect on learning.

This paper revealed that through merging metacognitive tools and learning processes one would be actually steering the learners unto a meta-learning educational journey since the learners are empowered to develop a better understanding of how they learn and guide them to construct strategies for their future learning in any domain. In this way children will really become agents of their own learning because:

1. The process of the Vee Heuristic lends itself beautifully for reflection and action.
2. Concept Maps offer a visual picture of what the learners have in their heads.
3. Let Me Learn advanced system is value added due to the lexicon used with intention and by revealing how each learner processes incoming information.

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CONCEPT MAPS AS TOOLS FOR SCIENTIFIC RESEARCH IN MICROBIOLOGY: A CASE STUDY

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Abstract. In scientific research there is often the need to increase the organization of data and to optimize communication of results either in a conference or as a scientific article. Researchers should be able to externalize their critical thinking, their problem solving skills and their ability to interconnect knowledge. Concept maps are pedagogical tools that help researchers to structure their practical ideas and results in useful ways. Concept mapping were used extensively to communicate and clarify ideas, help researchers see the relationships and the organization among concepts, solve problems, and support the design of their work. In this study, concept maps were used as a research tool by a team of research scientists. Our intent is to provide a rationale and explain the practical approach underlying our use of concept maps. A distinctive aspect of our use of maps is that rather than being only a tool for clarifying the ideas and results obtained, concept maps are tools that researchers can use to support their diary work. A case study is described using three different projects: the first approach concerns the use of concept maps to analyse and review a scientific article, the second is the use of concept maps to design a scientific work and the third one is the use of concept maps in protocols or detailed methods section for laboratory work.

1 Introduction

In accordance with the constructivist learning theory, learning is a process that consists not only in memorizing new facts but also by the assimilation of information into pre-existing framework of knowledge (Ausubel et al., 1978). It is therefore of utmost importance the use of powerful meta-cognitive learning tools that enable the construction of structural representations of knowledge. Researchers are supposed to be lifelong independent active learners and problem solvers (Dolmans & Schmidt, 1995) that can successfully analyze data and carry out comprehensive planning and delivery (Novak & Gowin, 1984; Baugh & Mellott, 1998; Schuster, 2000). Scientists are experts that should be considered for their richer knowledge structures, considering not only the relevant declarative information stored, but also the interconnections between knowledge. It is therefore important for science research to use concept mapping as a learning aid and evaluation tool of science work (Ruiz-Primo & Shevelson, 1996; Iuli & Helldén, 2004). Concept mapping is a tool that can promote problem solving and critical thinking (Dabbagh, 2001), thus enabling researchers to organize complex data, to process complex relationships and to measure important aspects of the researcher evolving skills. To create a map a researcher cannot rely only on fragments facts of the work but must have a general view of the entire situation, which requires logical, unambiguous and orderly presented data (Wilkes et al., 1999). Moreover, a researcher needs to construct correct and logically connected explanations of previous described concepts in a specific domain (Ellis et al., 2004). Meta-cognitive tools may be therefore useful not only to construct knowledge based on the enhanced understanding of the experimental events but also to externalize knowledge and thinking processes (McAleese, 1998; Sánchez-Quevedo et al., 2006). These processes will increase communication between individuals and teams allowing knowledge preservation in large complex domains. However, there are few studies in the microbiology and infectious disease domain literature (Fonseca et al., 2004) about the use of concept maps to analyze and review scientific articles, to design experimental work, and elaborate detailed protocols for diary laboratory work. As such, the purpose of this study was to present the case study of a research team that uses concept mapping as a tool for science research using three different projects as examples.

2 Procedure

This work reports the experience of a team of researchers that have used concept mapping since 1998 until present. Our team has developed a number of methods and processes that were useful in helping to formulate research projects and help the members of the team to initiate the use of concept maps as tools for scientific research. One PhD thesis (2007), two master thesis (1999 and 2006), two final graduation projects (2003 and 2005) and ten scientific articles (1998-2008) have been designed and prepared using concept maps. We used three different projects to describe our case study; one of the scientific articles of the PhD thesis and one section of the same thesis were used as representatives (Fonseca & Sousa, 2007; Fonseca, 2007). All the concept maps presented were constructed using the SmartDraw software (version 6.0).

Works	Author	Year	Domain
PhD Thesis	Fonseca AP	2007	Human Biology
Master Thesis	Fonseca AP	1999	Biomedical Engineering
	Extremina CI	2006	
Final Graduation Project	Extremina CI, Costa G	2003	Medical Microbiology
	Bento M, Martins M	2005	
			Journal or Book
Scientific article	Fonseca AP, Extremina CI	2008	*To be submitted*
	Fonseca AP, Granja PL, Nogueira JA, Oliveira DR, Barbosa MA	2001	J Mat Sci: Mat Med
	Fonseca AP, Extremina C, Fonseca AF, Sousa JC	2004	J Med Microbiol
	Fonseca AP, Sousa JC, Tenreiro R	2006	Rec Res Develop Microbiol
	Fonseca AP, Sousa JC	2007	J Applied Microbiol
	Fonseca AP, Sousa JC	2007	Int J Antimicrob Agents
	Fonseca AP, Correia P, Sousa JC, Tenreiro R	2007	FEMS Immunol Med Microbiol
	Fonseca AP, Correia P, Extremina CI, Sousa JC, Tenreiro R, Barros H	2008	*Under revision*
	Extremina CI, Fonseca AF, Granja PL, Fonseca AP	2008	*Submitted*
	Fonseca AP, Extremina CI	2008	*Submitted*

Table 1: Scientific works that have been designed using concept maps

2.1 Analysis of a scientific article

In scientific research the work is usually published in scientific journals, which have instructions for authors that they have to fulfill. In literature review and in the preparation of articles is important the analysis of published literature in various different journals with different instructions. It may seem that analyzing many articles using concept mapping as a tool it is time consuming, but the mapping process of a few indispensable articles allow to identify important theories and concepts (Kinchin, 2005a,b). One way to organize, clarify and unify the ideas is to transform the important sections of an article in concept maps.

The first project to be described was the analysis of an article published in 2007 in Journal of Applied Microbiology entitled: Effect of antibiotic-induced morphological changes on surface properties, motility and adhesion of nosocomial *Pseudomonas aeruginosa* strains under different physiological states (Fonseca & Sousa, 2007). Three different maps of each section were constructed: introduction, materials and methods and conclusions. According to classification of cognitive structures (Kinchin et al, 2000; Hay & Kinchin, 2006) Figure 1 represents a network, which is an indicative of a deep learning.

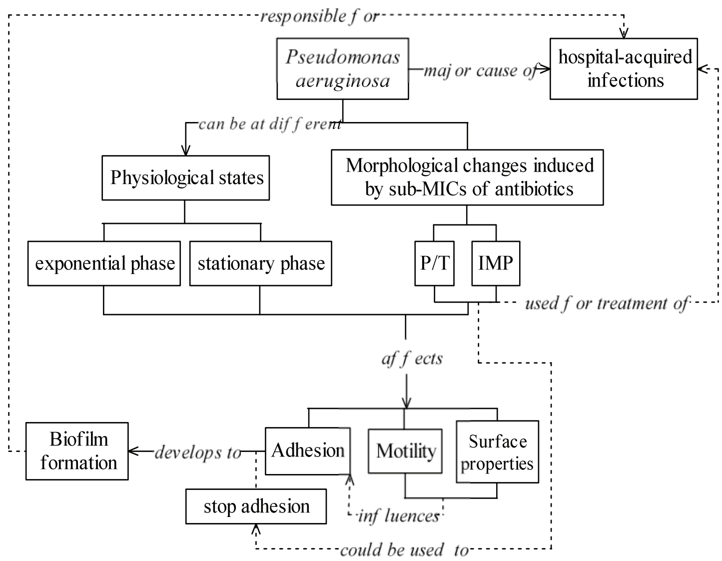

Figure 1. A concept map from the Introduction section (Fonseca & Sousa, 2007).

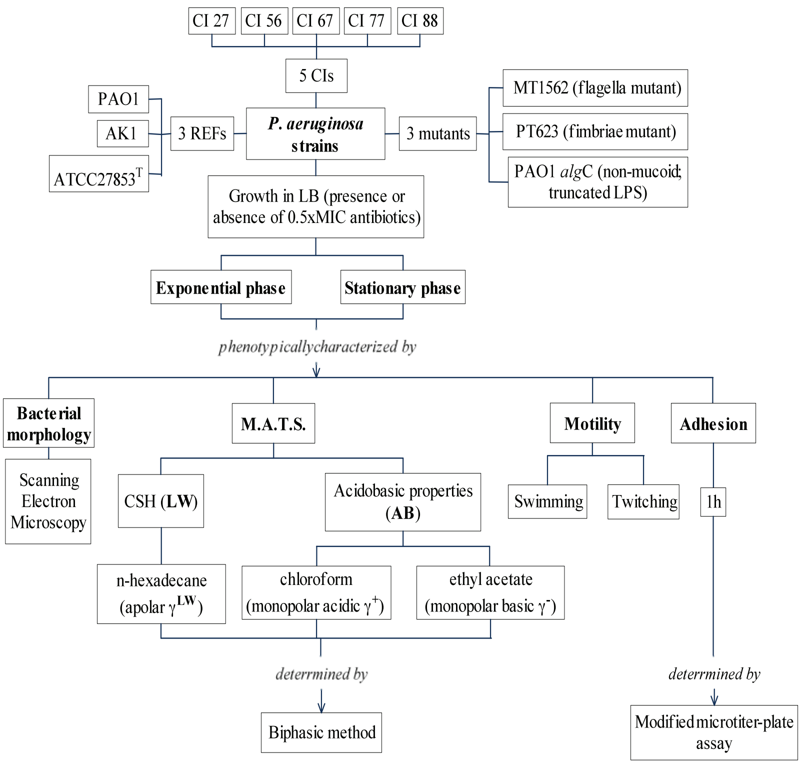

Figure 2. A concept map from the Materials and Methods section (Fonseca & Sousa, 2007).

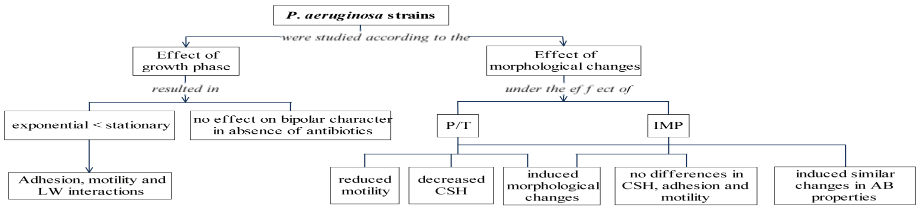

Figure 3. A concept map from the conclusions (Fonseca & Sousa, 2007).

2.2 Design of a scientific work/project

To prepare a scientific work/project it is necessary to organize all the objectives and ideas in a practical and useful way. Our main objectives in this project were to present an example showing how concept mapping can promote higher integration and organization of knowledge during the various stages of the project design. In fact, concept maps can be used to structure a scientific work while constructing it, thus helping to clarify the sequence of an argument. Moreover, these maps can summarize sections of the work and highlight connections being therefore useful for novice team members or by others to increase scientific output (Kinchin, 2005b).

The Aims from the PhD thesis (Fonseca, 2007) used by the research team are exemplified in Figure 4 using concept mapping as a tool. This concept map was constructed in order to work as an advance organizer, which "activates appropriate cognitive structures" and guides the researcher while analyzing the entire work within a context (Kinchin, 2005b).

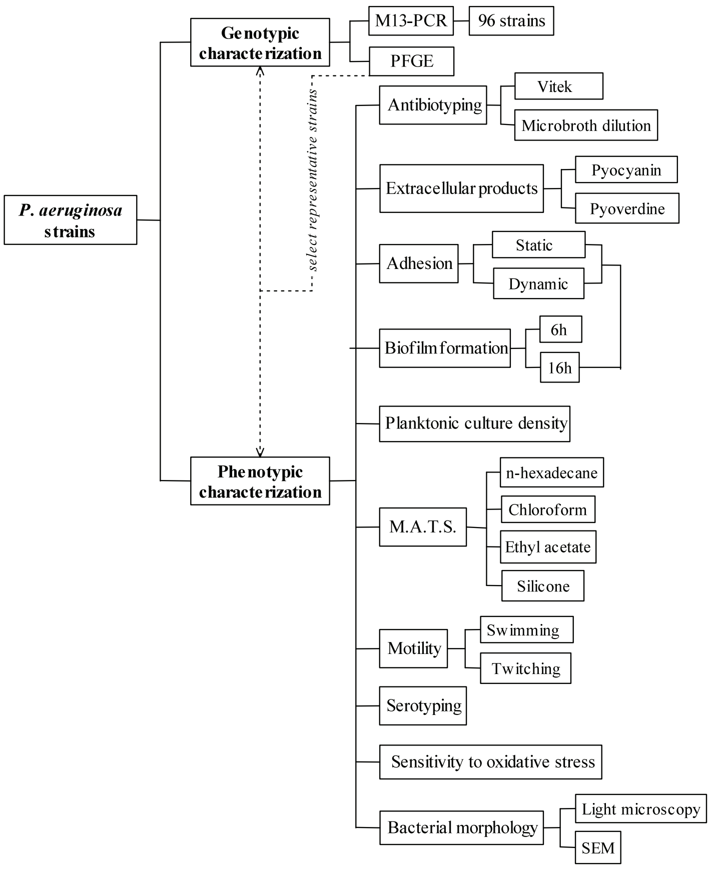

Figure 4. Concept map for the Aims of a scientific work (Adapted from Fonseca, 2007).

2.3 *Construction of a protocol for laboratory work*

In diary work on laboratories it is crucial to have the protocols organized and available to follow step by step all the procedures. When the researchers are working and at the same time have to look to the procedures it is difficult to follow up the steps of a protocol in Word or pdf format. The link between the writing process and the concept maps is critical because it is necessary to share all the information with others who are not concept map users. The level of detail of the concept map compared with the writing process is dependent of the experience and knowledge of the researcher. The greater the researchers experience in concept map construction the greater the level of detail.

In this project the protocols were constructed as concept maps which made them more useful as an individual tool or for sharing with others. It is presented one of the examples in Figure 5, which is composed of a series of chains that indicate goal-orientation, as can be expected in an experimental protocol (Kinchin et al, 2000; Hay & Kinchin, 2006).

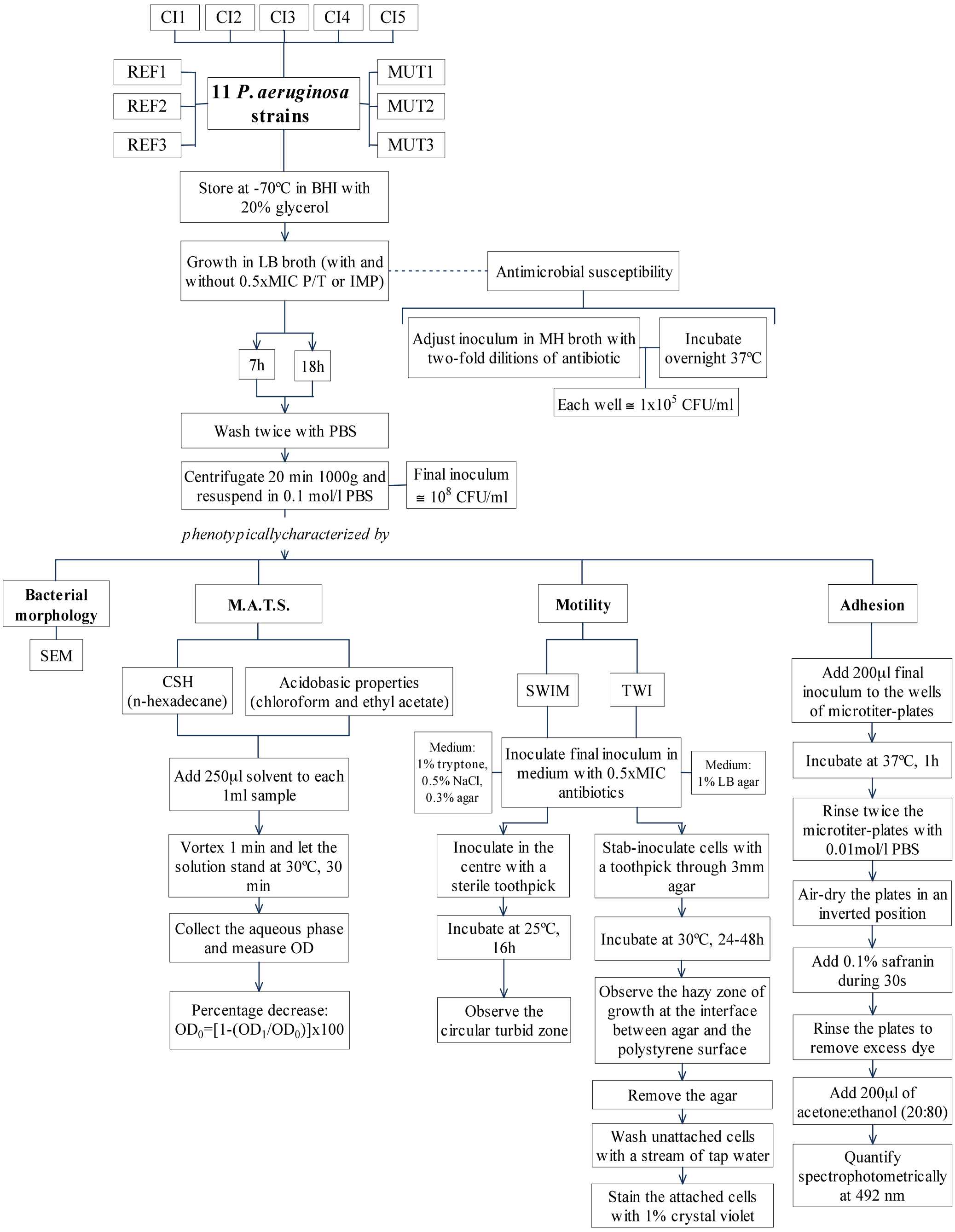

Figure 5. Protocol as a concept map for laboratory work.

3 Summary

This article reports a case study describing three projects involving the use of concept maps to clarify, organize and integrate ideas and information in a specific scientific research domain. Our research team concluded that concept mapping provides a useful way to share knowledge and information and to see connections in different works/projects and scientific articles. Concept maps that result from the analysis of a scientific article, the design of a project or from a construction of a protocol are useful tools for communication and share of knowledge between individuals and the research team. These meta-cognitive tools can facilitate knowledge understanding, retrieval and application promoting therefore the increase in scientific output for all the team members and the optimization of the presentation skills by new research team members.

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CONCEPT MAPS AND CMAPTOOLS: A COGNITIVE WRITING SYSTEM FOR THE GENERAL DEVELOPMENT OF THOUGHT IN SCHOLAR AGE

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Abstract. This paper wants to analyze some possibilities offered by technological solutions available nowadays as *CmapTools*; it wants to suggest some possible progressive outlines aimed to satisfy the need of developing a language/natural thought, and an educational method to meaningful and complex thought in the area of *Computer Supported Collaborative Learning* to be used in the period of primary school which is considered as a crucial time for the development of the thought organ in children of 5/6 to 10/11 years old. The examples taken from the results of common didactic work carried out in classroom describe the technological solutions offered by the software CmapTools to develop the human cognitive ability and in specific "*to the passage from unconscious concepts to conscious concepts along the extension of scholar age"* (Vygotskij) and they show in a evident way and for their own virtues the problematic fecundity of the interaction between language faculty, representation and development of complex thought.

1 Introduction

From the year 2000 to the 2008 we have experimented a didactic process in continuity through natural rhythms of observation, doing and narrating, characterized by inter-disciplinary and collaborative methods aimed to find the most favorable interactive conditions that are going to determine the development of language/thought faculty in the child.

We've started our research with the intent of understanding the internal relation between thought and word at the very first stages of children's development, in pre-school age, in order to carry out a formative process in continuity from infant school to primary school. The systematic observation of the child's language experience in regular school's activities has led us to collect many examples that show how, from the beginning of thought/language development, *the meaning is a global unit of thought and word; generalization and word meaning are synonymous; word meanings develop; education is motif and cause of the thought evolution* (Vygotskij, 1934). For the above reasons, we've concentrated our research on a specific and well defined aspect: how the language/thought faculty develops in children along the period of school age (from 5/6 to 10/11 years old) through writing, (writing as the semiotic faculty that precedes marks creation and that has been defined by *Saussure as " la faculté linguistique par excellence"*), in that special form of social interaction that is carried out at school (Giombini, 2004, p.274)

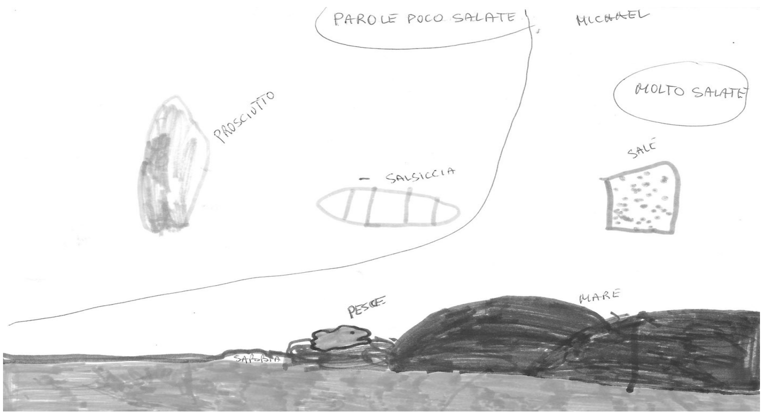
Actually, starting from the first experimental activities on inter-relation between development and written language (mark-sign, linear writing, meta-cognitive writing – concept maps, hyper-text writing – CmapTools) together with meditative and complex thought development, we can see that this field has grown wider and wider and it's constantly changing and renovating, thanks to the innovation brought up by the software Cmap Tools and thanks also to neuroscience and empiric observations of schoolchildren expressive-language activities that confirm the genetic structure of language/thought faculty. Since then, the research program on concept maps and CmapTools, both considered as a writing's tool princeps and offered to the mind that by directing and mediating its own thoughts through signs and words learns to build itself up, shows in an evident way and for its own virtues the problematic fecundity of the interaction between language faculty, development and performance of complex thought.

Maybe, after eighty years since the ceaseless question put by Vygotskij *"how is the passage from unconscious concepts to conscious concepts accomplished along the schoolchild's age"* (Vygotskij, p. 233), thanks to science and technology, we have finally found an instrument as CmapTools -- "intelligent" writing interface -- that allows us to plan a linguistic learning context worth the answer.

2 The relation between thought and word. Drawings and maps for an empiric confirmation.

We share with Vygotskij, the idea that the relation between thought and word is a process, a real and proper movement that goes from thought to word and from word to thought. In this sense, I think that the following image speaks for itself in a clear way by showing how in children of pre-school age *the thought doesn't express* *itself in the word, but it accomplish itself in the word* and, as Vygotskij had written, we can talk about a process of becoming (unit of being or not being) of the thought [*mysl'*] in the word.

The following drawing shows a step of a systematic work carried out with children of 4/5 years old finalized to the monitoring of the conceptual competence of words. The teacher has asked children to "write" (through drawings) all the salted words that they knew, after several direct experiences aimed to discovering the sense of taste. The picture shows Michael's (5years old) "written" answer stating that "*very little salted words*" are *ham*, *sausages*, while "*very salted words*" are *salt* and *sea*. But when the teacher asked Michael: - why do you think that the fish is salted? –



Michael answered this question saying that "the fish lives into the sea". Michael's thought *is not express in the word, but it is accomplished in the word/drawing of the fish.*

Since early age throughout the sign-drawing, children show us how the word and the thing from that drawn are going to form a unique structure, but also that the meaning of words is not constant. In this drawing, as for all the other children's drawings, we find *"that no matter the associative bound is, the child decided between word and impression of the thing indicated from such a word, nevertheless the meaning of the word is not established forever. It changes in the course of the development. It modifies according to different thought's functions. It represent a more dynamic creation rather than static"* (Vygotskij, p.333). In fact, we can't say that Michael would sustain the idea that the fish is salted for its nature only because it lives in a salted place, the sea.

Drawing is a kind of language used by small children as an intimate shape of thought. It 's rarely understood as described by Antoine de Saint Exupéry (1943) in the book "The little prince". Unlike oral language that is in most cases a shape of dialogic language (from dialogue), drawing, as for all writings, is a shape of mono-logic language (from monologue) so as the inner language. And as the inner language it "preserves" and "express" grammar and syntax.

At the beginning of primary school, the child (5/6 years old) already owns a well developed linguistic and communicative modality (even if only for himself) organized in principles and rules described by Vygotskij as "*a tendency to a predicative attitude, to the reduction of the physic aspect (phonologic) of language, to the prevalence of sense on the word's meaning, to the agglutination of the semantic units, to the influence of senses, to the idiomatic language, to the elision and omission"* and he ascribed all **to inner language**.

Daily school activity show us how the passage from "**silent" language**, the one of the mind, to the spoken one, is not only a simple vocalization of the inner language, but it is a reconstruction of syntax absolutely original and specific of the inner language semantic and phonetic structure that rise to other structural shapes in the external language.

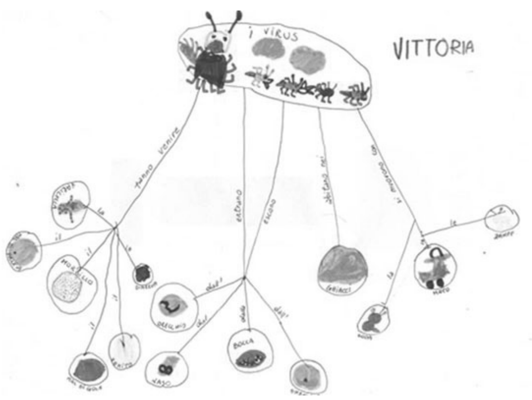
As we all know, *agglutination, omission, substitution of semantic units, omission, postposition of characters in a word, difficulty on recognition and in the reproduction of graphemes, inversion of characters, predicative attitude, lack of subject, predominance of sense on meaning of word*, are going to characterize the written production of every child as learning narration/ reading/ writing in a measure inversely proportional to age and to the awareness of the new modality of writing/ communication, and are going to fade slowly until they disappear altogether around the age of 8 (this is the result that all our schoolchildren achieve around the age of 7 and none of them develop that disturbance of the learning process called dyslexia).

However, it’s well known that the persistence of these difficulties beyond the 8 years of age (it seldom regresses spontaneously) is a sign of dyslexia, a serious problem of knowledge that can vary from some memory difficulties to a real impediment in the learning of writing / reading processes.

To obtain a formative success for everybody is a reward not only auspicious, but in our experience acquirable. In this view, maps are a precious instrument because through the reading of conceptual and hypertext writing an extraordinary world of didactic perspectives it’s widening to the teacher.
In fact, in our experience:

- In this view, concept maps and hypertext writing become a spontaneous evidence of the trials of the child’s mind and they outline the passage from one level of communication to another, from a linguistic modality to another: from the speech of himself to the speech for others, from oral to writing, from internal language to external language.
- These maps “photograph” the relation between thought and word and they document how every steps of development correspond not only to a particular structure of the word meaning, but also to a specific relation between thought and language determined by this structure and they help the teacher in his/her difficult activity of observation and prevention.
- The maps “signal” how the mind works during the time of acquisition / transition from one organizing modality of speech (language mono-logic/ inner) to the other (language dialogic and written language in use), from one level of conscience to another, from several formalized competences (disciplinary) to others, and if the mind has not clear the strategies and the information that will allow itself to carry out a given request, the brain answers using known modalities, even if not suitable, because those are the “only ones it can use”.

The enclosed images comment by their own this phenomena. They have been written by two little girls unable to use alphabetical writing because of 4/5 years of age. They have been redacted after a conversation on the absence of many companions ill. After a statement given by one of the present child on the reason that kept so many schoolchildren at home, “because they got the *virus of influenza*”, the teacher asked the present children to write “all that they knew about the word virus”. The maps show ability of thinking for complexes and a different grade of development of the external language.



Victoria has started “writing” for the others and her drawings have a communicative form, but she hasn’t learned yet to write her first name (her name Victoria has been written by the teacher). Apparently, Sofia is writing more for herself than for the others: her marks are very “essential”, more like scribbles than drawings. But two hints on Sofia’s map are telling us that we are assisting to that passage which will take Sofia *from the inner language mono-logic to the external language, from one level of conscience to another, from a series of formalized competences (drawing for herself: scribbles; drawing for others: figure, map) to other competences (alphabetical writing).*

In fact, in a concept knot it appears an anthropomorphic figure (virus that get the child sick) and on the border of the paper the spontaneous writing of her name Sofia. The result is though SOFPIA. What can at a first glance be only a mistake (the sound of “F” is repeated twice: in the grapheme “F” correctly, in the grapheme “P” wrongly), it’s in fact a reasoning. “**F**” and “**P**” are similar sounds and the word “Sofia” reminds the graphic structure of both graphemes. The little girl in her uncertainty has decided to use both. Now, from the modality of the teacher’s intervention would depend if, in which way and how long will Sofia be able to resolve successfully her doubt , after that she will automatically get the correct correspondence sounds / graphemes F – P for ever .

3 CmapTools: "The habitat" in which mind learns to build itself up

Following the theories on the development of the language faculty described by Chomsky (1979) and Vygotskij that had underlined how the child develops his own faculty of language/thought species-specified through linguistic experience involving actively the re-construction of meanings and using Vygotskij's concept of tri-polar thought development (individual mind, other individuals and reality) in which the social mediation is the indispensable pivot of any mental construction, we have conceived / used the *hypertext writing for concept maps as the "habitat"* in which the mind learns to build itself up.

Without a project of continuity, from the year 2003 to 2008, conceptual maps and CmapTools have been offered to children as the instrument and the interface of writing/writings from the very beginning of primary school. The "reading" of all the meta-linguistic writings (free or didactically structured) produced by children has given us an extraordinary chance of empiric observation of the thought-word activity and we decided to direct the curricular didactic action towards a "scientific" project (less arbitrary and casual) of the learning context of every single child (Giombini, 2004, 2006).

We owe to the re-reading of Vygotskij, Chomsky and Novak's theories, through the filigree of "writing" expressed in a conceptual, meta-linguistic, hypertext and cognitive modality thanks to the new "immaterial" support the computer, this vision of extraordinary didactic perspectives. In fact, the monitoring of the functional role of the word's meaning in the act of thinking, along the period of school age, has supplied us, in time, with remarkable confirmations on the "generative" capacities of language faculty's principles and rules and has allowed us to represent in its basic outlines how the evolution of the verbal thought process takes place in its whole.

Knowing how the system mind/brain (thought organ) learns, what specialized systems it uses in order to learn and what strategies planes for reutilizing competences and notions, has given us the opportunity to meditate on the problem of variability and dynamicity of the relation between thought and word and has brought us to "investigate" on the problem of meanings generalization and the functional role of the word's meaning in the act of thinking.

But above all, it has allowed us to perform two crucial actions for the interaction teaching / learning / thought development as follow: a) *to detect the optimal period of learning;* b) *to plane in a consistent way the formative actions* since the evidences of our data show in a constant and clear way that:

- it's in the *discard (difference) between individual concept maps (evidence of the inferior threshold of learning) and expert concept map (evidence of the superior threshold of learning)* that the central point of thought's faculty development is placed in every child. **The point** was called by Montessori "**sensitive period**" and by Vygotskij "**area of next development**" in which *"learning wakes up and keeps alive several functions that are usually latent, while formal discipline of each subject is the field in which the influence of learning is accomplished on development"*(Vygotskij, p. 275);
- it's in the writing of the expert map and moreover in its hypertext re-writing on CmapTools interface (used for research activities with the possibility of finding sources given by the software for documentation) where, for every child, the *possibility* of improving *from what he's able to do on his own to what he learns doing in collaboration* is accomplished. *This is going to be a sensitive point that will eventually characterize the dynamics of his development and his success in the learning activity"* (Vygotskij, p. 276);
- it's in the writing / reading of the *structure maps (Maps of Learning Objects)* where the child *becomes aware* of his intellectual product (map of a dominium and of his knowledge) and he empathically fixes a new threshold of learning by reaching a different level of conscience.
- it's in the ability of cognitive and shared reading first and in the tribute to the conceptual expert writing on CmapTools later, that the teacher's maieutic (from greek "maieutiké – Socratic method) role is exercised as a truly and proper "Magister ludi"; it's in taking part (primus inter pares) to the collective hypertext writing where the teacher has the possibility to indicate new aims and draw new routes and while doing that he/she determines the exact area of the next disciplinary development of the whole group and of each single individual.

4 CmapTools as the “intelligent” interface of the measure of generality

For a hundred years, the human social language has been “conditioned” by technologies that have given us the communicative interactivity, typical of oral language, but only in the private area. Finally, the computer and internet have given the word back to the world and social language has been able to reuse its own dialogic essence with the bilateral direction (I→R; I←R) that was lost.
But all this is happening on a level different from oral, which is a characteristic princeps of language faculty species-specific anthropologically evolved, and it reuses the dialogical structure of communication on a different and improper linguistic level: the writing.

This is the point of all the issue: for the first time in its history, the language, the most powerful mean for exercising the specie’s vocation, requires the complete mastery of expanded competences of writing. An expressive typology of sign-meaningful that doesn’t reproduce the oral language evolution but that requires a high level of abstraction for its minimum development.

In the brain’s development as an organ, the acquisition of abstract competence is not a question of time, or “maturity” of mind. The innate faculties of the thought organ, in order to develop the potentialities inborn in the genetic background, require that certain “physiological” conditions are respected and promoted. For the child, passing to abstract language means not using the mental language and so *not using the word,* that in Saussure’s (1916) description it corresponds to the psychic aspect of human language and it has an individual sense, *but the representation of the word* (meaning of word in the language or generalization).
This phenomena is not without consequences: if the world’s language is mostly expressed in *“sense”* instead of *“meaning”* it means having more difficulties in the child’s development of the language faculty.

Difficulty in learning, misconceptions, difficulty in expressing his/her own thought, it’s always a **question of words**, *Learning Objects of the mind***.** Words are Learning Objects of thought: real and proper knowledge units auto-consistent, with communicative and didactic intents well established, of reduced dimensions, to use and use endlessly in apprehension contexts, easy to get through descriptions or tutors. For children, words are meaning units they play with, just like they do with Lego bricks (Giombini, 2004, p. 274). But, very often the child is not aware that elementary meaning units (words, lines, graphemes, numbers…) can be put together to make sentences grammatically correct but without meaning or that combining the lexicon elements through syntax we can form meaningful sentences grammatically correct without a correspondence in reality. The autonomy of language interpretations is the base of creativity, but also of illusions / misconceptions.

In the fracture between *sense* and *meaning* lays the first point of the whole issue. The second point, not less important, is the passage from one level of speech to another. To overcome this passage, the greater difficulty is in the fact that mind’s language is only thought and not spoken, and this gives much more problems to the child that is acquiring the mastering of writing. Initially, written language is a process without interlocutors but the child himself; it’s a speech without real sound, it’s only thought and it needs a representation, a symbolization. A learning child finds more difficult to acquire written language than oral language, just like algebra is more difficult than mathematic.

A systematic use of CmapTools creates the right conditions to reach the level of abstraction in a harmonious way, since it helps the child in the hard development of the writing’s skill and in the conceptual development of words. Throughout the traceable “resources” of computer’s memory or web with internet, the teaching of new shapes of words or concepts becomes the source of a superior development of the concepts already own by the child and this work establishes “*not the end, but the beginning of the development of scientific concepts”* (Vygotskij, p. 208)

The following images no.1 and no. 2 are the “*Structure Maps /L.O.*” redacted by schoolchildren of different age and in different time. The first was redacted by children of 7/8 with the help of the teacher, while the second one by children of 9/10 on their own. We decided to call them “*Structure maps*” because they reassume the entire process. It has been possible to make them thanks to the versatility of the software CmapTools. In the place of the concept word, the knot has the map (or resource) used to illustrate a conceptual generalization. Tanks to that function that allows us to write concepts with drawings, even children unable to use writing can draw, we have transformed maps in drawings and then we have reused them in order to visualize all the expansions and connections.

“Structure maps” are an extraordinary didactic moment / instrument, since they are map that re-illustrate, by visualizing it, the whole work carried out in both ways, individually and collaborative.

They document a modular work, scanned by the following passages: **a**) writing of individual concept maps as evidence of meaning competence and ability to think for complex thoughts → **b**) redaction of expert hypertext cmaps as evidence of competences of more individuals (cooperative learning; E-learning)→ **c**) redaction of "Structure maps" to become aware of the entire process. They all are obligatory steps finalized to the development of " *a complete series of functions, as the voluntary attention, logical memory, abstraction* (points **a**, **b**), *comparison and distinction* (point **c**)" that Vygotskij had placed at the centre of the development of language / thought faculty: they start from "*development of concepts and meanings of words"* and end in the production of Learning Objects.

"Structure maps" represent the visual and organizing instrument of "*becoming aware"* since they "re-discuss" the conceptual organization of the whole conscience dominium, they also become fantastic inductors of memory and, above all, the extraordinary and effective occasion for the development of **measure of generality**. In fact, through the re-collocation of all the expansions generated by "the conceptual explosion" of the mother's-word, the child experiments directly "*that the existence of a measure of generality of any concept allows the relation with all the other concepts, the possibility to get from certain concepts to others, the foundation of relations among them according to numerous ways infinitely variable and the possibility of equivalence in concepts* [Vygotskij, p. 300]. In establishing logical and casual links (WHO, WHERE,WHEN, WHAT, WHY) *children become aware of their own thought and concepts will eventually evolve from unconscious to conscious.*

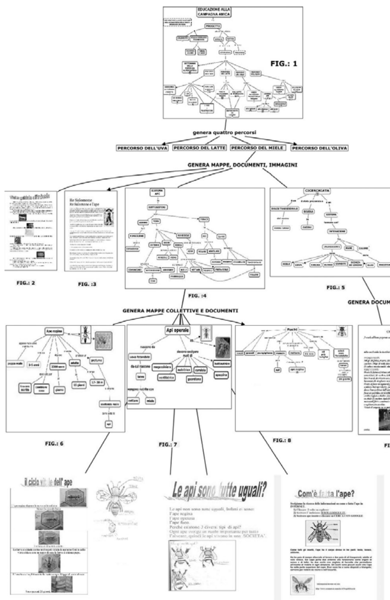


Fig.: 1 Structure map, L.O. "THE HONEY" 7/8 years

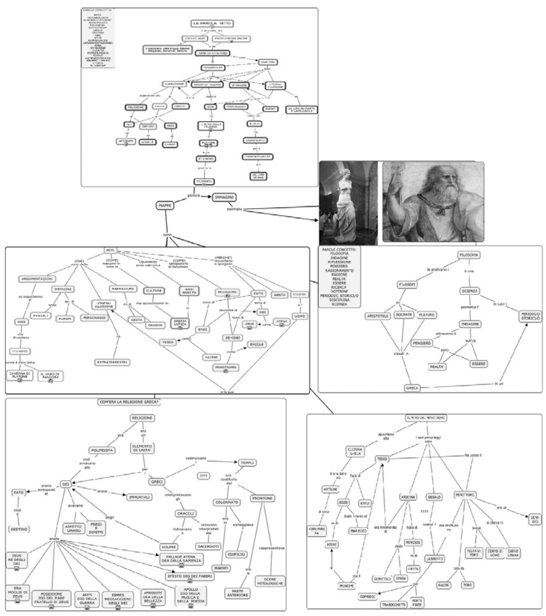


Fig.: 2 Structure map, L.O. "THE MYTH" 10 years

Apparently similar, these two images document how very small children (from the second year of primary school: 7/8 years) can use successfully hypertext writing in its full function provided by CmapTools and, above all, they are evidence of how as soon as the child *"masters a kind of superior structure as to become aware and learn how to use certain concepts, he's able to transfer the structure directly, once he has established it on concepts previously elaborated"* (Vygotskij, p. 283). This is exactly what has happened with the "invention" of writing maps: it was sufficient that children understood that a map could be saved as an image in order to establish automatically the following relation: map=image→ knot=image→ structure map.
Maps in general and the structure map in particular perform a fundamental function: they help the child to mature trough language the category of adversative relations, which, in a spontaneous reflective thought and without an adults' help, appear much later than casual relations. The editing among hypertext maps, and especially the collaborative and final redaction of the structure map, imposes definite choices as to "attack" an answer instead of another. *In this way, the child, throughout an experience with* "ALTHOUGH", *becomes aware of the different relations sited on a superior level of conscience and of argumentation, the abstract ones.*

The following images, figure no.3 and no.4, are frames of the structure map " The Myth". These hypertext maps show how the systematic use of CmapTools together with the representation's method of concept maps, allow children to be the protagonists of their own development, since they become aware and can guide the will of the act of learning. In fact as you can see in the image no.3, the map of "WORD MYTH" is illustrated from a meaning's point of view with the help of dictionary and web research (which the map's authors of 9/10 point out with ability of quotation) and it's declined in its **four generalizations** of meanings: **narration, argumentation,**

image, utopia / illusion (a myth is…). Each of these generalizations gives life to a research. For example, the generalization “**argumentation**” develops several concepts (**argumentation** → unfold→ “**ideas** ” → example→ “**The allegory of cave** ” → of→ “**Plato**” → is a→ “**philosopher**” →practices → “**philosophy**”) that are here illustrated with other maps (philosophy) or documents (the allegory of cave) or images found in history of art (Plato).

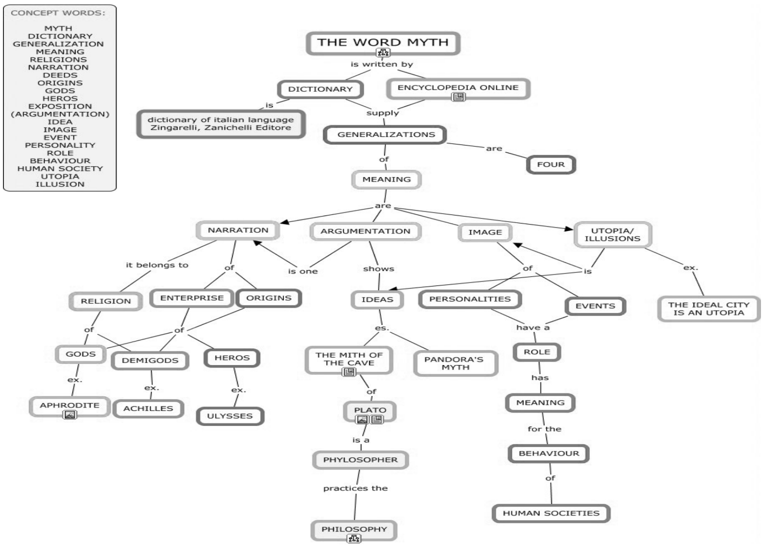


Fig.: 3 Hypertext map “WORD MYTH”: (10 years)

The image no.4, the hypertext map “Myths”, is a resource of the “Word myth”(fig. no.3) and it develops according to logical and casual links the following enquirers : **who, where, when, how, why.** In this way the child, in outlining his dominium of conscience, acquires concrete disciplinary competences (language, history, geography, history of literature, Greek / Roman’s mythology, history of art) and methodological competences (research’s methodology, also on web, and acquisition of competence of meta-linguistic writing). This map, as for all the other maps, is an opportunity for complex reflective thought, since it shows and demonstrates how becoming aware it’s not only a sum of the speech’s functional parts and/or of thought, but also a development of the links (linear and sequential thought and processing and reticular thought).

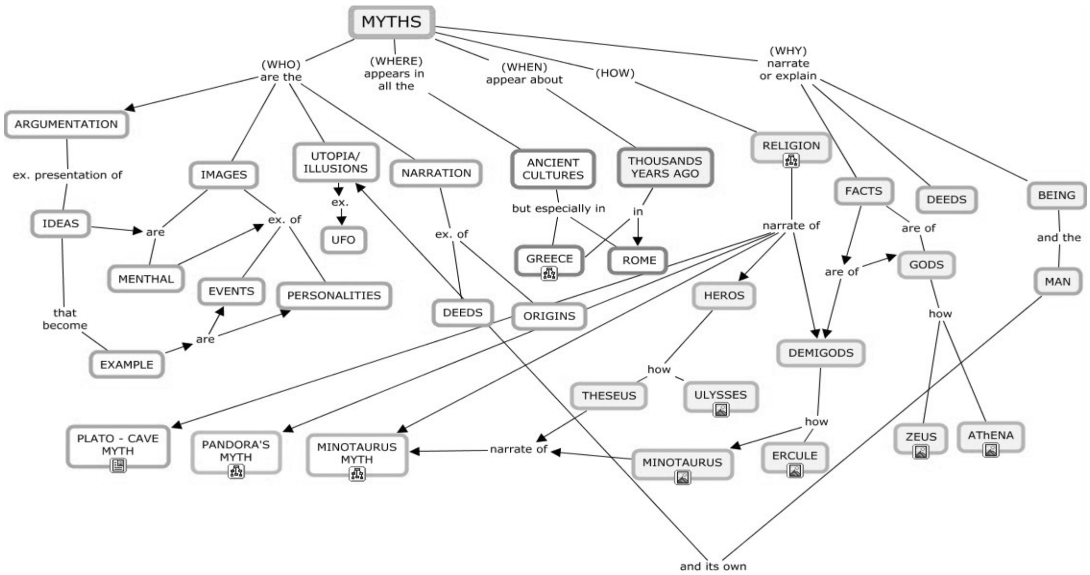


Fig.: 4 Hypertext map “MYTHS” (10 years)

5 Summary

Finally, the systematic use of concept maps and CmapTools, as a writing system, supplies the mind with the most favorable conditions, which, through mediation signs, learns to build itself up. In specific, it sustains in an harmonious way the passage from an organizing modality of the theme (inner speech/mono-logic) to another (dialogic speech and written language in use), from one level of conscience to another, from several formalized competences (disciplinary) to others superior competences. But, above all, concept maps and CmapTools allow the monitoring of the whole process, from the steps of thought's development for complexes already covered by the child to a new and superior step, the abstract one that in most cases takes place around the age of 10 (slightly earlier than the one indicated by Vygotskij of 12/13).

6 Acknowledgements

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CONCEPT MAPS AND SHORT-ANSWER TESTS: PROBING PUPILS' LEARNING AND COGNITIVE STRUCTURE

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Abstract. The purpose of our research was to study what concept maps reveal about pupils' learning compared to teacher-designed school achievement tests (short-answer questions). Twenty pupils (10–13 years), with ample of experience constructing concept maps, had projects in which they constructed a concept map at the beginning and end of a learning project. Achievement tests were used in the balanced statistical design of four replications. Twice the achievement test was presented after the concept maps and twice the achievement test was given between the concept maps. Nine of the student answers were transformed proposition by proposition into concept maps. The numbers of relevant concepts and propositions were used as measures of meaningful learning. The reliability varied 0.73–0.95. The mode of knowledge representation accounted for variation of measures of meaningful learning 45–89 per cent. (Eta squared coefficients varied from 0.45–0.89.) Individually, pupils had more relevant concepts and propositions in teacher-made tests than they were able to reveal by their own concept maps. By their self-constructed concept maps pupils reveal what they think are the most relevant items in their metacognition. When a teacher helps pupils by asking short questions, the same pupils always write statistically significantly more, and it is evident that they have learnt much more than revealed by their concept maps. They express partly different and complementary knowledge in concept maps and in teacher-made achievement tests. The result suggests that it would be wise for teachers to use both concept maps and short answer tests while monitoring and promoting their pupils' learning.

1 Introduction

Concept maps have been argued to be a measure of cognitive structure (Novak & Gowin 1984, 138; Novak 1998, 52; Stoddart & al. 2000, 1223; Thompson & Mintzes 2002). An important problem is how much of pupils' knowledge and its structure we are able to represent by concept maps. Edwards and Fraser (1983, 24) provide empirical evidence for their claim "… concept maps were as accurate as interviews for revealing student comprehension of concepts." Novak & Cañas (2008) argue in similar fashion referring to Edwards and Fraser (1983). As far as we know no one has tried to use short-answer tests to probe pupils' understanding about the same content area as they made concept maps. In this paper we present a quasi-experimental design and results of statistical tests concerning this issue.

According to Åhlberg (1990) all concepts become accurate only in relation to other concepts, as a part of a developing conceptual structure. That is why it is important to monitor and promote development of pupils' conceptual structures.

2 Methods

From all we knew about concept maps, we created the research problem and planned the methods by which these problems would be answered. Research problem: Are there statistically significant differences between pupils' own concept maps and their answers to the short answer questions in a teacher-made achievement test as indicators of pupils' quality of learning and understanding? The following research methods were used to answer research problems: (1) Counting personal sums of concepts and propositions from the last student-made concept maps; (2) Counting sums of concepts and propositions from pupils' answers to a short-answer test. (3) Using a teacher-made concept map as a tool; (4) Paired-samples t-test and (5) Eta-squared –coefficients used as measures of effect-size.

2.1 Research design

The research and teaching are designed to test practicality of concept mapping and teacher-made short-answer achievement tests. Design experiments (Brown 1992, Brown and Campione 1996, Collins 1996) were planned and executed in a school class in Eastern Finland. There were two series of design experiments: the first one from 1997 to 2000 with one class (group of pupils) and from 2000 to 2002 with another class. In the first series of design experiments (1997–2000) there were 19 pupils, 11 girls and 8 boys in the class. In the second series of design experiments (2000–2003) there were 20 pupils, 10 girls and 10 boys in the class. When we examined the learning in these long series of design experiments, we have used sums of relevant concepts and sums of relevant propositions as the best available indicators of the quality of learning. The more relevant concepts and relevant propositions a pupil has, the more likely s/he is able to learn more and more meaningfully.

In this paper we present only the results of four design experiments in which teacher-made short-answer achievement tests were used as a control to pupils' concept maps. In two of the design experiments teacher-made short-answer achievement test was presented after the last pupil-made concept maps, in two design experiment teacher-made short-answer achievement test was presented before the last pupil-made concept maps. The total research design of four design experiments was balanced as regards to timing of concept mapping and short answer testing. The design experiments were as follows:

1) The Atmosphere-design experiment: The first concept maps were created on March 26, 2001, the second concept maps were created on April 19, 2001. The teacher-made short-answer test was on May 3, 2001.
2) The Human Biology-design experiment: The first concept maps were constructed on October 19, 2001, the second concept maps on January 17, 2002. The teacher-made short-answer test was on January 17, 2002.
3) The Australia-design experiment: The first concept maps were constructed on January 17, 2003. The teacher-made, short-answer test was on February 19, 2003. The second concept maps were made on February 21, 2003.
4) The Sun and Planets-design experiment: The first concept maps were made on April 4, 2003. The teacher-made, short-answer test was on April 24, 2003. The second concept maps were done on April 28, 2003.

The answers to the teacher made short-answer test of the nine intensively studied pupils were transformed into concept maps. Sums of relevant concepts and sums of relevant propositions were calculated.

2.2 Generalizations in quantitative and qualitative research: Importance of replications

Our research data are not random samples, but purposeful samples, which are information rich (applying Patton 1990, 181–185 and Patton 2002, 242). Statistical tests are used, but not for statistically generalizing to any accurate population. In educational sciences there is the problem that populations are constantly changing. This means that there is no real way to take a random sample of pupils or teachers in the strict statistical sense. Strictly speaking, there is no statistically sound way of statistical generalization to any larger population. But theoretical generalization is possible, because the researched pupils and their teacher are cases of real pupils and real teachers respectively (Cook, Leviton & Shadish 1985, 763 – 764; Yin 1998; de Vaus 2002, 148). Purposeful samples of real pupils allow us to conclude that under the similar conditions, similar phenomena are likely to happen.

In this article statistical significance tests are applied to test how much the figures from the samples differ from what would be expected by chance. This is a test of whether variation in the sample statistically significantly differs from random variation. Testing four times, allow us further check whether the statistical analysis results of purposeful samples the tentative regularities stand up to the repeated statistical testing. In behavioural and educational sciences there are far too few replications (Cook & Campbell 1979, 79–80; Rosenthal & Rosnow 1984, 181–191; Robinson & Levin 1997; Thompson 1997).

2.3 Data Analyses and Findings

Principal Vuokko Ahoranta, MSc collected the data. She has used concept maps and Vee heuristics regularly with her pupils since 1997, about four to five times per school year. She had started to work with these pupils in the same school year when the data was collected. All pupils were involved and very attentive during their part in the design experiments. They knew and were pleased that they collaborated in educational research as a part of their teacher's university studies. The validity of concept maps was checked using pupil interviews from time to time. In the four design-experiments, pupil's answers to teacher-made short-answer test provided an extra validity check of pupils' concept maps.

Data was analyzed both qualitatively and quantitatively (Miles and Huberman 1994; Miles & Huberman 2002; Cresswell 2002, 559-601). Following Åhlberg & Ahoranta (2004), we assume that meaningful learning has at least two practical indicators: personal sums of relevant concepts and of relevant propositions. Variation of meaningful learning is indicated by variation of sums of relevant concepts and sums of relevant propositions, both of which are calculated from concept maps. They are the best available indicators of meaningful learning and understanding. These figures were statistically analyzed.

We present two examples of a pupil's concept maps and an example of a teacher-constructed concept map based on a pupil's answers in the teacher-made, short-answer test.

Atmosphere-design experiment

Pupils #208 constructed himself the following concept maps: Figures 1 and 2. We have added short interpretations of the maps.

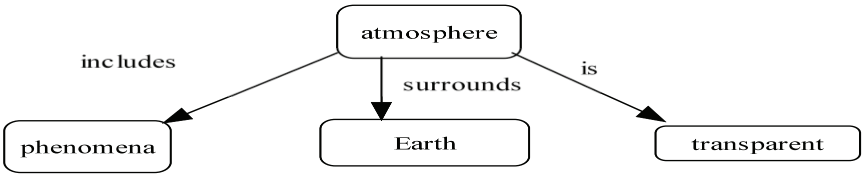

Figure 1. The first concept map of the pupil #208 at the beginning of the design experiment on Atmosphere.

Interpretation of Figure 1: There is an appropriate hierarchy in the first concept map of this design experiment. There are four relevant concepts and three relevant propositions. There are no clear misconceptions.

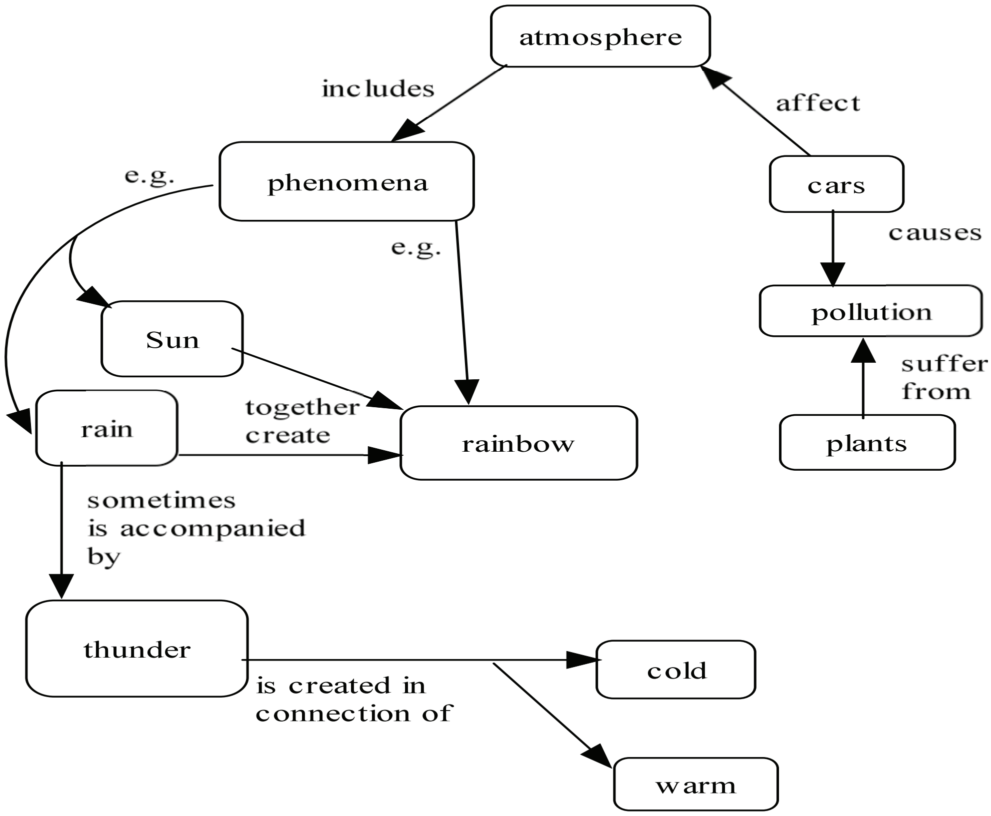

Figure 2. The last concept map of the pupil #208 at the end of the design experiment on Atmosphere.

Interpretation of Figure 2: There is an appropriate hierarchy in the concept map. There are 11 relevant concepts and 12 relevant propositions. There are no clear misconceptions. Based on the number on links to and from each concept, we find three equally central concepts in this concept map: 'phenomena', 'rainbow' and 'thunder'. Each of them is connected to other concepts by three links. Probably these concepts were the most prominent in the pupil's thinking when he constructed his concept map.

Atmosphere: Transforming a pupil's writing (short answers) to a concept map

The teacher-made short-answer questions/tasks were as follows: 1) What gases the air is made of? 2) Explain how the wind is formed; 3) What do you know about air pressure? 4) In which ways the atmosphere is important for humankind? 5) How is a rainbow created? 6) How are the Northern lights created? 7) What are the uses of air for humans? 8) What causes air pollution and how it can be prevented? 9) How is a thunderstorm created? 10) How is burning linked to the earlier questions and their answers?

The content validity of the test is high, because these short questions correspond with the local curriculum, its main themes and concepts. We transformed the pupils' answers to a concept map (Figure 3).

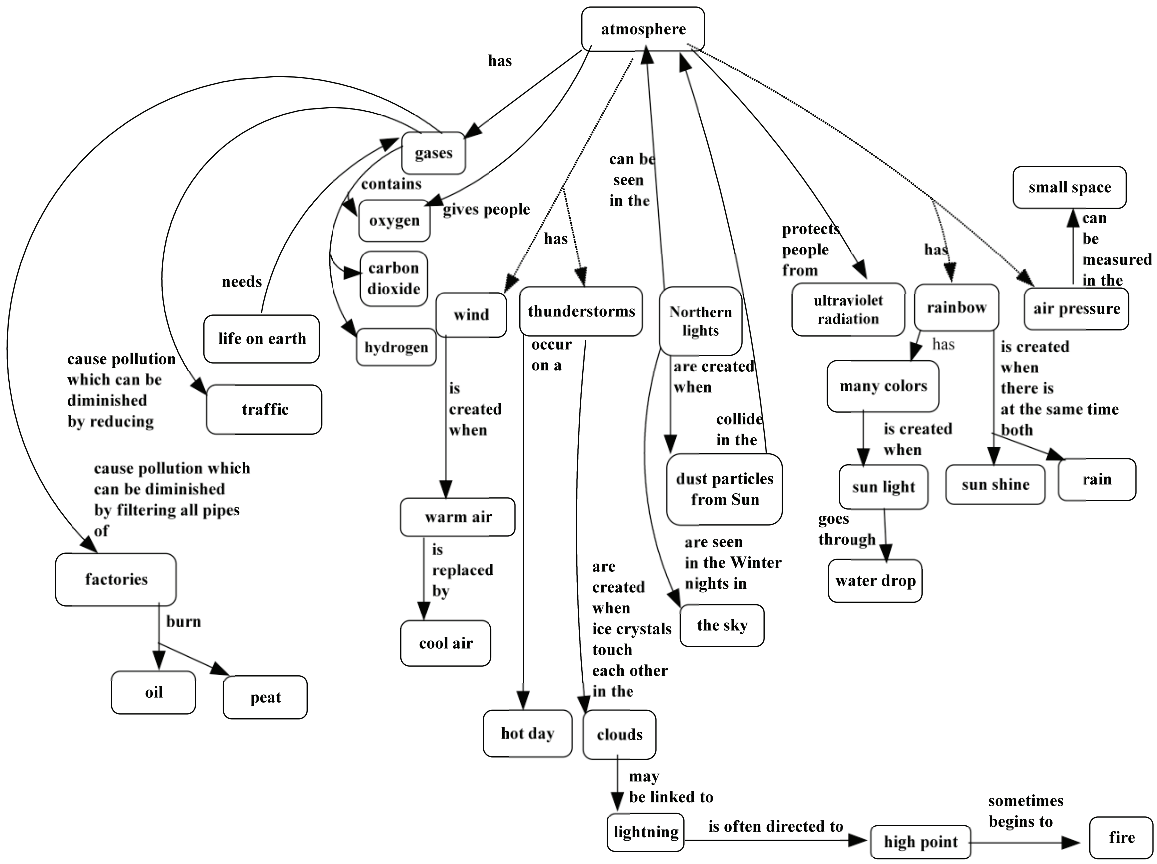

Figure 3. An example of a concept map which the teacher constructed transforming proposition by proposition pupil #208's answers in the teacher-made short-answer test on 'Atmosphere'.

Interpretation of Figure 3: When a pupil herself/himself constructs a concept map s/he can only take into the concept map what is in her/his metacognition. However, all pupils were able to provide much more information when explicitly asked in the teacher-made short-answer test. These two methods to gather knowledge about what and how pupils learn and think are complementary. Both provide useful knowledge for both pupil and teachers. It is interesting to learn that the most central concept of this pupil's thinking was 'gases'. It has seven links with other concepts. 'Atmosphere' has nine links with other concepts, but four of them are inferred implicit links.

2.4 Effect sizes

The fifth edition of APA (2001, 25-26) Publication manual emphasizes the importance of reporting effect sizes, e.g., product moment r-squared, and eta-squared (or effect size r-squared). Kier (1999, 95–96), Kramer & Rosenthal (1999, 63), Rosenthal and DiMatteo (2001, 72) and Field and Hole (2003, 166, 170, 180) present how eta-coefficient or "the effect size r" can be calculated from t-values and sums of squares resulting from Student's t-test and F-values and sums of squares of ANOVA.

2.5 Evaluating the quality of concept maps

There are many methods for evaluating the reliability and validity of concept maps (e.g., Ruiz-Primo and Shavelson 1996; Rice, Ryan, Samson 1998; McLure, Donak and Suen 1999; Ruiz-Primo, Schultz, Li and Shavelson 2001). These tests are based on Ausubelian learning theory as Novak and Gowin (1984) applied it to concept maps. Åhlberg and Ahoranta (2004) have presented a more general approach based on the idea that concepts and propositions are basic units of thinking, and in evaluation the main task is to check how many concepts and propositions are relevant.

Cronbach's alphas based on the total sum of number of concepts and propositions in the beginning, middle and in the end of the design experiments in the four intensively studied design experiments described in this report are:

- Atmosphere, based on 1st cmap, 2nd cmap, cmap based on teacher-made achievement test: alpha = 0.95
- Human biology, based on 1st cmap, 2nd cmap, cmap based on teacher-made achievement test: alpha = 0.92
- Australia, based on 1st cmap, cmap based on teacher-made achievement test, 2nd concept map: alpha = 0.88
- Sun and planets: based on 1st cmap, cmap based on teacher-made achievement test, 2nd cmap: alpha = 0.73.

3 Results and discussion

Are there statistically significant differences between pupils' own concept maps and their answers to the short answer questions in a teacher-made achievement test as indicators of pupils' quality of learning and understanding?

A paired-samples t-test was used to find out whether there is a statistically significant difference between pupils' own last concept maps and teacher-constructed concept maps based on pupils' answers in the short-answer test. The results of these tests make it possible to calculate, how much variation of meaningful learning (as indicated by the number of relevant concepts and relevant propositions) does a form of knowledge representation (self-made concept maps vs. teacher-made concept map from pupils' answers to short-answer test) statistically explain.

Atmosphere–design experiment

Data are presented in Table 1.

			Sum of relevant concepts			Sum of relevant propositions		
subjects	School achievement level	Sex	The 1st concept map	The 2nd concept map	Short-answer-test	The 1st concept map	The 2nd concept map	Short-answer-test
201	Advanced	male	6	17	36	5	17	40
202	advanced	female	8	21	48	7	20	53
203	advanced	female	11	24	50	10	23	61
204	average	female	5	24	29	4	23	31
205	average	male	2	11	21	1	10	22
206	average	female	9	15	35	8	14	39
207	low	male	7	8	32	6	7	33
208	low	male	4	11	31	3	10	33
209	low	female	3	5	27	2	4	28

Table 1: The data of the design experiment of 'Atmosphere'.

The statistical results are presented in Table 2. There are statistically significant differences both in the number of relevant concepts and propositions between the last pupil-constructed concept map and the teacher-constructed concept map of pupils' answers to the short-answer test. The mode of pupils' knowledge presentation explains statistically almost 90 per cent of the variation of personal sums of both concepts and propositions.

Variables, which are explained statistically by the form of knowledge representation	Arithmetic means (M), standard deviations (s) and correlation between measurements (r_{12})	t = t-test value, df = degrees of freedom, p = statistical probability (2 – tailed)	Eta squared = effect size correlation between the second concept map and teacher-made short-answer test, based on personal sums of relevant concept/propositions .	percentage of variation explained
Personal sums of relevant **concepts** in the second concept map and the concept map based on short-answer test	The sample of pupils M_1 = 15.11, s1 = 6.92 M_2 = 34.33, s2 = 9.43 r_{12} = 0.641, df = 7, p = 0.063	t = -7.907, df = 8, p = 0.000	0.89	89%
Personal sums of relevant **propositions** in the second concept map and the concept map based on short-answer test	The sample of nine pupils M_1 = 14.22, s1 = 6.96 M_2 = 37.78, s2 = 12.32 r_{12} = 0.670, df = 7, p = 0.048	t = -7.65, df = 8, p = 0.000	0.88	88%

Table 2: The statistical results of the design experiment of 'Atmosphere'.

Human Biology–design experiment

There are statistically significant differences both in the number of relevant concepts (t = -6.433, df = 8, p = 0.000, Eta squared = 0.84) and propositions (t = -6.228, df = 8, p = 0.000, Eta squared = 0.83) between the last pupil-constructed concept map and the teacher-constructed concept map of pupils' answers to the short-answer test. The mode of pupils' knowledge presentation explains statistically over 80 per cent of the variation of personal sums of both concepts and propositions.

Australia–design experiment

There are statistically significant differences both in the number of relevant concepts (t = -2.573, df = 8, p = 0.033, Eta squared = 0.45) and propositions (t = -2.705 df = 8, p = 0.027, Eta squared = 0.48) between the last pupil-constructed concept map and the teacher-constructed concept map of pupils' answers to the short-answer test. The mode of pupils' knowledge presentation explains statistically over 45 per cent of the variation of personal sums of both concepts and propositions.

Sun and Planets–design experiment

There are statistically significant differences both in the number of relevant concepts (t = -5.244, df = 8, p = 0.001, Eta squared = 0.77) and propositions (t = -5.146, df = 8, p = 0.001, Eta squared = 0.77) between the last pupil-constructed concept map and the teacher-constructed concept map of pupils' answers to the short-answer test. The mode of pupils' knowledge presentation explains statistically 77 per cent of the variation of personal sums of both concepts and propositions.

4 General Discussion

All pupils were involved and very attentive during their part in the design experiments. They knew and were pleased that they were used in educational research as a part of their teacher's university studies. This may have resulted in the Pygmalion effect or the Rosenthal effect that motivates the pupils to be more effective than usually. When anything new is introduced into a classroom, many kinds of unintended side effects may result (Ball 1988, 490). The Pygmalion side effect was used in this study in a positive way. We expected that all pupils would learn more and better while using concept maps and Vee heuristics, because both concept maps and Vee heuristics are designed and tested metacognitive tools to promote meaningful learning. Pupils' concept maps reveal to pupils themselves and to their teacher much more detailed knowledge than they earlier imagined possible to know about their learning.

In four design experiments pupil's answers to a teacher-made short-answer test provided an extra check on the corresponding pupil's concept maps. The authors were surprised to learn from pupils' answers to the short-answer test, that pupils knew much more than they presented in their concept maps. However, what was presented in the pupils' concept maps was often, in the answers to short-answer tests, but not always all. These two ways to probe pupils' learning and understanding are complementary. Principal Vuokko Ahoranta has continually discussed concept maps with her pupils, and her conclusion is that when pupils construct their concept maps they put into them everything relevant that comes into their minds. Improved concept maps then provide pupils and their teacher knowledge about pupils' metacognition. When remembering and knowledge construction is facilitated by short questions in the test situation, much more comes into mind. Our results differ from Edward's and Fraser's (1983, 24) conclusions after using pupil interviews: "… concept maps were as accurate as interviews for revealing student comprehension of concepts." These results need independent checking in other contexts. There is a need for replications in other classrooms, with larger populations of pupils and teachers.

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CONCEPT MAPS AS A TEACHING/LEARNING TOOL IN SECONDARY SCHOOL MATHEMATICS. ANALYSIS OF AN EXPERIENCE

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Abstract: This paper presents an experiment designed to test the different uses of concept maps (CMs), as a tool to promote meaningful learning (ML) in the teaching/learning process for a math topic. The precise aims are to assess its usefulness in the design of an innovative instructional module (IM) on the topic of proportionality, as a learning tool to help students grasp the content of the module, as a means of assessing students' prior knowledge of the topic and monitoring their progress. In a standard schoolroom setting, the implementation of a theoretically grounded IM gave a group of second-grade secondary students at the Ikastola San Fermin School the opportunity to learn about the topic of proportionality in a more meaningful manner. This is demonstrated by statistical analysis of ML indicators, using the SPSS (Statistical Package for the Social Sciences) and an evaluation of the evolution of the students' CMs throughout the instructional module.

1 Introduction

The Second International Conference on Concept Mapping (San José, Costa Rica, 2006) included a special session on Concept Mapping in mathematics, moderated by leading researchers: Nancy R. Romance from Florida Atlantic University (USA), Jean Schmittau from State University of New York at Binghamton (USA) and Karoline Afamasaga-Fuata'i from University of New England (Australia). The proceedings of that session reproduce a number of case-studies illustrating the use of concept maps (CMs) in the teaching of mathematics. These include the use of CMs to help students to grasp the concept of the positional system (Schmittau & Vagliardo, 590-597); the development of a Concept Mapping approach to the teaching of mathematics in secondary schools (Caldwell, Al-Rubaee, Lipkin, Caldwell & Campese, 2006); a study by Pérez Flores (2006); the evaluation of multidimensional CMs (Huerta, 2006); and CMs in the learning stages of Van Hiele's educational model (Esteban Duarte, Vasco Agudelo & Bedoya Beltrán, 2006).

These communications and spaces for the development of more thorough math instruction are mentioned here to highlight the validity and importance of CM's in the area of high school mathematics. A new field is therefore opening up for the use of CM's as an unbeatable tool for the promotion of meaningful learning (ML) and the replacement of rote learning (RL) among students and the detection of certain patterns that can be considered valid learning predictors.

Also presented at the above-mentioned Congress was a study by Pozueta, Guruceaga & González (2006), in which the main objective was to detect ML indicators through the analysis of students' CMs, in a context in which second-grade secondary students worked with proportionality topics from the area of mathematics. In anticipation of the effectiveness of CMs as a tool to promote ML in students, they were used in the design and delivery of the instruction on the topic, and also to assess the knowledge acquired by the students. The results illustrated the effectiveness of CMs in achieving more meaningful learning in the evaluated students.

As noted in the cited work, proportionality is not a simple concept Rapetti (2003) notes the complexity involved in acquiring the notion of proportion and claims that students need to be presented with a range of situations varying in numerical complexity and in the type of magnitudes related, because some students have difficulty when faced with the need to consider quantities in relation to one another, that is, when required to see them in other than absolute terms. This stands in the way of their understanding what they need to learn in order to grasp the notion of proportionality.

When it comes to seeking references for the analysis of proportionality in our teaching/learning context, it is important to take into account the research that has gone into defining the concepts of ratio and/or proportion. Lesh et al. (1988) examine and compare the views of various authors such as Vergnaud, Schwartz and Kaput, among others, regarding the nature of ratios.

Other outstanding contributions include Freudenthal (1983), who highlights the importance of distinguishing between internal (or "within") ratios and external (or "between") ratios. Internal ratios are those that compare different quantities belonging to the same system, and external ratios are those that compare different quantities belonging to different systems. Nesher and Sukenik (1989), in a brief overview of previous research on the concepts of ratio and proportion, mention a common procedure widely used in many studies, which is to administer a test including ratio problems (written or oral and with or without illustrations) and analyse students' answers in terms of the strategies they use to solve the problems. They report that one of the commonest errors in children of various age groups is the use of the additive strategy, whereby children see the relationship between the ratios as the difference between the terms and fail to capture its multiplicative nature.

These theoretical considerations have led to our interest in advancing with the use of CMs in the topic of proportionality, testing its usefulness in various practical aspects, such as the design of an instructional module (IM) for the topic, based on the promotion of positive attitudes, the identification of students' prior notions and conceptually transparent curricular and instructional material on the one hand, and the analysis of the evolution of the students' learning process on the other, all of which will promote meaningful learning in students in the early years of secondary education.

2 Research design and development

This paper sets out to test different uses of CMs as a tool to promote meaningful learning, in other words, to assess their usefulness in tasks such as:

- Designing an innovative IM for the topic of proportionality, consistent with Ausubel's (1976) recommendation to take into account what students already know about the target topic. The maps drawn by the students prior to instruction can be used to identify the starting point of the learning process for each of them. Ausubel also proposes beginning the instruction process by presenting the more inclusive concepts relating to the target topic, before dealing with the more specific concepts. Hence the need to clarify which concepts are to be included in the instruction, what significance they will have, what hierarchical relationships and reconciliations there are between them, and how this frame of reference relates to what students already know. Novak (1998) recommends teachers to create a reference CM on which they should set out all the concepts, both inclusive and specific, relating to the chosen topic, in this case, proportionality. Such a reference CM (see Figure 1) serves to identify the most significant conceptual nodes and informs the design and sequencing of the activities.
- To be used as a learning tool by students to grasp the instructional content.
- To identify students' prior knowledge of the topic and analyse the evolution of their learning process. This will be done by means of a comparative analysis of the maps drawn by the students before and after instruction, following the model presented by Guruceaga & González (2004) and focusing on the presence or absence of certain features (see Table 1). In this way, a student's CM will provide a tool to reveal the degree of ML achieved, or alternatively show that the learning has been less meaningful and more of a rote or mechanical nature. The indicators are shown below:

Table 1. Learning indicators.

Indicators of rote/mechanical learning	Indicators of meaningful learning
• No clear differentiation between concepts and linking phrases; direction of the relationships between concepts not shown	• Clear differentiation between concepts and linking phrases; shows the direction of the relationships between concepts
• A minor number of concepts are used	• Most of concepts are used
• A high frequency of erroneous propositions: illogical conceptual hierarchies	• A decreasing trend in erroneous propositions
• An incorrect hierarchical ordering of concepts in terms of their inclusivity	• There is coherence in the hierarchical organisation of the concepts in terms of their inclusivity
• The most inclusive concepts are not identified	• The most inclusive concept is identified
• Shows long linear relationships, chaining of concepts	• Examples of super-ordination of an inclusive concept • Progressive differentiation between inclusive concepts • Linear relationships between concepts are fewer or totally absent
• Crossed links are few in number and erroneous: a sign of weak integrative reconciliations	• There are numerous crossed links revealing high-level integrative reconciliations

This study was conducted during the 2006-2007 school year in the Pamplona municipal area in a state-aided school (San Fermin Ikastola), where students of all stages, infant, primary, secondary and high school, are taught in the Basque language. The research, which was performed by a highly-experienced secondary mathematics teacher, was structured in various stages:

1. The first step was to create a reference map of the kind mentioned above (see Figure1), pitched to the level of second grade secondary students.

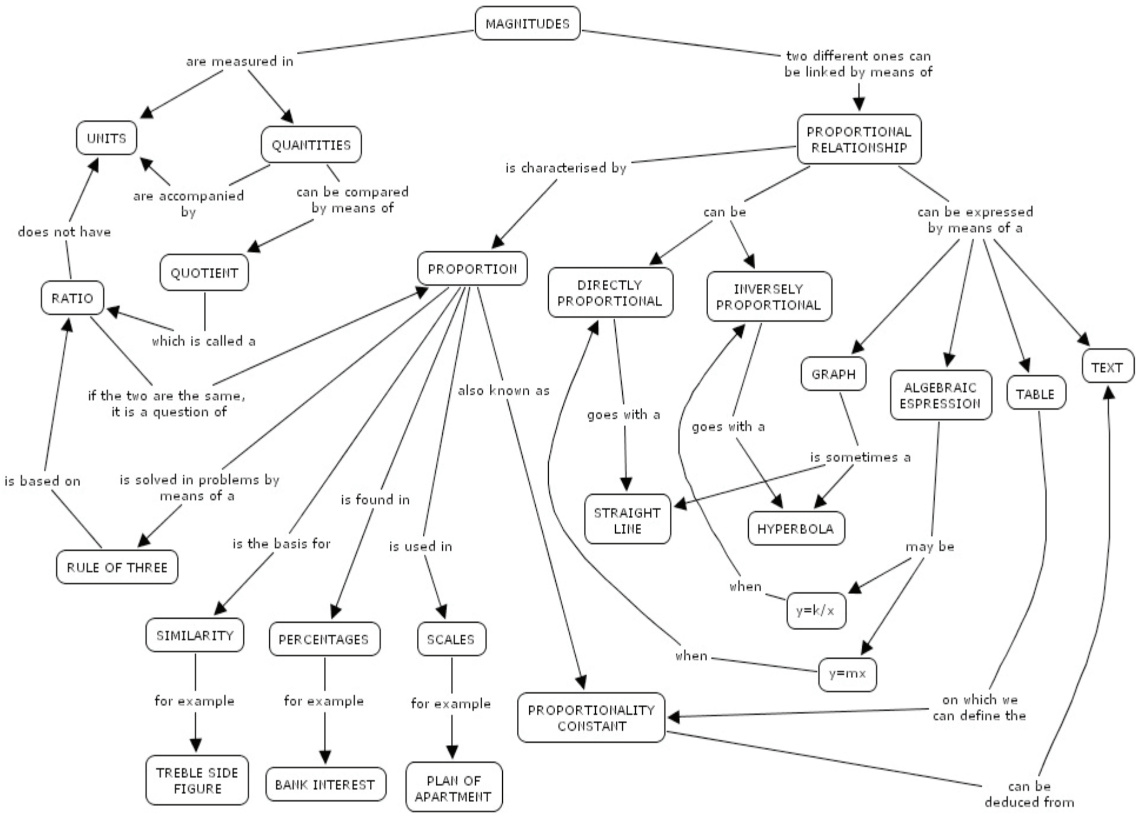

Figure 1. Reference map (Pozueta, 2003).

Twenty-five concepts were selected and the main relationships between them defined according to the teaching aims established in the IM. It should be stressed at this point that the aim of the module was to present and teach proportionality, starting with mathematical situations involving ratio, such as similarity, percentages and scales. The last level in the CM hierarchy therefore shows concrete examples of these situations. The map does not mention the necessary condition of congruence of corresponding angles to define similarity of figures; it refers only to the role of proportional reasoning. The map was also designed to make a clear distinction between ratio defined as a relationship between different quantities of the same magnitude and the proportional relationship that may exist between two different magnitudes, and the various ways in which this proportional relationship can be expressed. Thus, the four ways of expressing a relationship between two magnitudes appear on the right hand side of the map, each labelled to show whether it is a directly proportional or inversely proportional relationship. The definition of ***ratio*** is one that constitutes a violation of Freudenthal's (1983) interpretation, but it is the one that appears in the vast majority of textbooks for the teaching of mathematics in the first grades of secondary education.

2. Three groups of second grade secondary students, a total of 84 individuals, drew a CM prior to instruction. For this they were given the same list of 25 concepts used in the reference map. Figure 2 shows one student's initial map, in which it is possible to observe the few concepts used and the absence of important links.

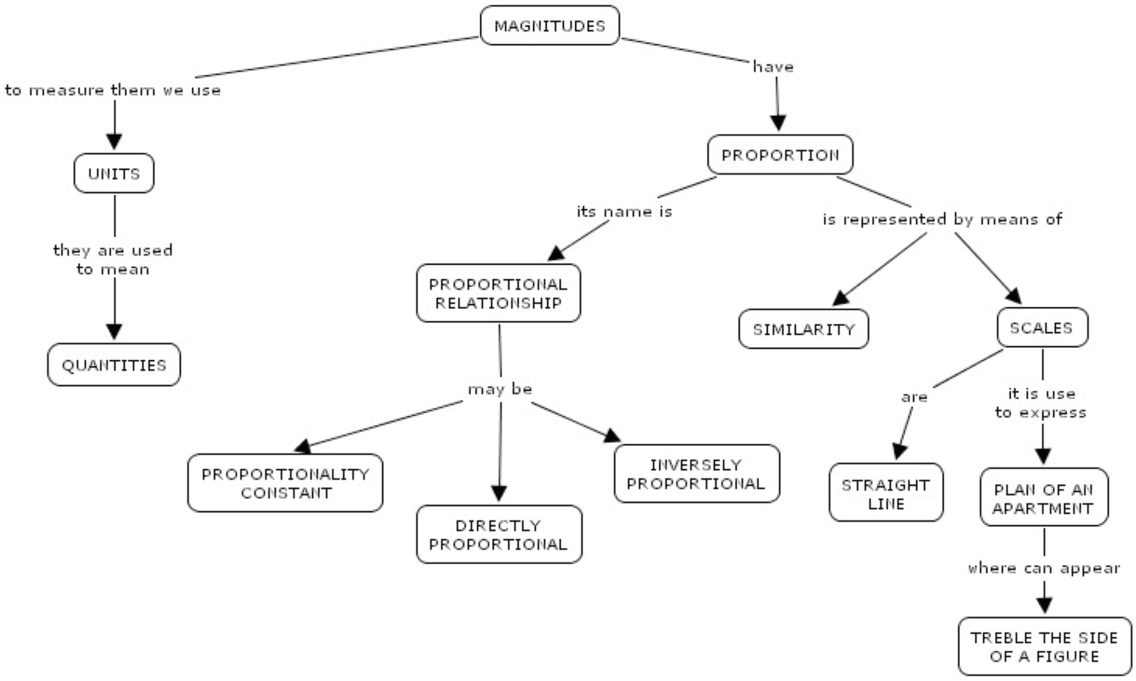

Figure 2. I. A.´s first map.

3. These maps served to reveal the point of departure for each student's learning process and informed the design of the innovative IM on proportionality. In general terms, the instruction followed the second grade mathematics program, but it should be noted that the related concepts usually appear in textbooks separately under different topic headings: *proportionality, similarity, scales, percentages, linear functions, etc.* … hence the need to relate them within the above-mentioned context of the construction of the reference map. The structure of the instructional module was adapted from Project LEAP (Learning about Ecology, Animals and Plants, 1995). Under this approach, activities are grouped into three phases: *introduction, focusing and summary*. The process begins with the presentation of the most inclusive concepts, after which progressive differentiations and the more significant integrative reconciliations are made. The final stage is the application of the information discussed throughout the instruction period. Ideas from several published texts were used in the design of the activities for this module, which was written in the Basque language ready for presentation in the classroom.

4. The teacher did not use the same approach with all three groups when giving the instruction during the second term of the school year. 29 students from one class were designated to be the control group, and the other two classes, that is a total of 55 students, made up the study group. The innovative IM was used in the two classes that made up the study group and the chosen methodology required students to work in small groups of five during the three formal phases of the module. In the control group, the topic of proportionality was dealt with in a more traditional manner, following the sequence suggested in the text book, without any clear distinction between the introductory, focus and summary stages, and students worked individually through some of the programmed activities. The last activity in the instructional module for all the students was for each to construct his/her own final CM from the same 25 concepts used in the map prior to instruction. Figure 3 shows a post instruction map by the same author of the pre-instruction map shown earlier. It is important to note the improvement achieved by this student, the second map bearing a fairly close resemblance to the reference map produced by the teacher.

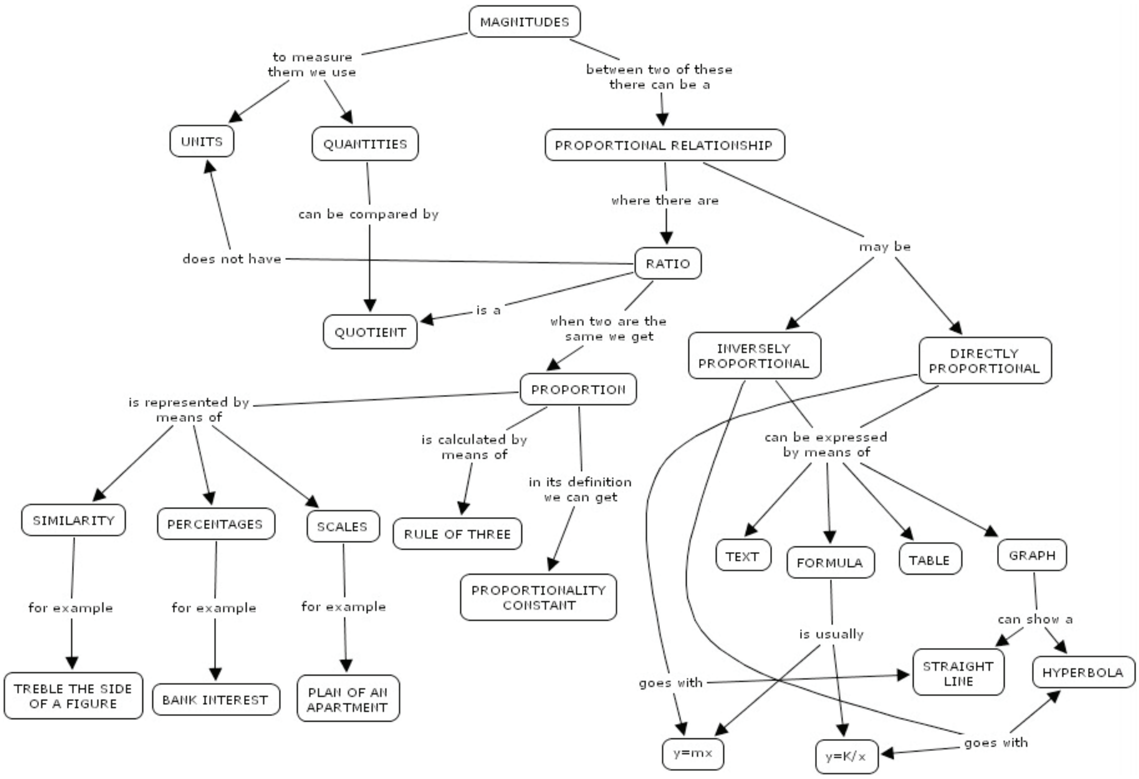

Figure 3. I. A.´s final map.

5. The series of variables defined for the comparative analysis of the CMs of all 84 students, before and after delivery of the instructional module, were based on the indicators shown in Table 1 above:

   - V_1 Evidence of the student's ability to make a clear distinction between concepts and linking words and accurately represent the direction of the relationships between concepts. A qualitative variable that takes a value of YES or NO depending on the presence or absence of such evidence.
   - V_2 The number of concepts used. A quantitative variable.
   - V_3 Clear identification of the most inclusive concept. A qualitative variable that takes a value of YES or NO, according to whether or not the most inclusive concept is accurately identified.
   - V_4 Percentage of faulty propositions relative to total number of propositions made by the student. A quantitative variable.
   - V_5 Coherence in the hierarchical arrangement of concepts by level of inclusivity. A qualitative variable that takes a value of YES or NO, depending on the presence or absence of a logical hierarchical structure.
   - V_6 An example of the super-ordination of an inclusive concept. A qualitative variable that takes a value of YES or NO, depending whether the map shows a relationship between the concepts of ***ratio*** and ***proportional relationship*** or not.
   - V_7 Complex progressive differentiation of the more inclusive concepts. A qualitative variable with three categories: NONE if there is no presence, SOME if one inclusive concept has been differentiated or HIGH if two or more inclusive concepts have been differentiated.
   - V_8 Sequences of linear relationships between concepts. A qualitative variable that takes a value of YES or NO, depending whether there are more than three linear sequences or not.
   - V_9 Number of valid crosslinks. A quantitative variable.

3 Discussion and results

The SPSS (Statistical Package for the Social Sciences) was used in this research to obtain the results of the comparative analysis of the CMs of the 84 students, before and after delivery of the instructional module.

The baseline homogeneity of the treatment and control groups was tested using an equality of means test for the quantitative variables and homogeneity tests for the qualitative variables. The following table (see Table 2), which gives the corresponding means, the category percentages of the qualitative variables, and the significance level of the tests performed, confirms the baseline homogeneity of the two groups, that is, absence of significant variation in any of the variables considered.

Table 2. Baseline comparison of the treatment and control groups.

variable	Treatment group		Control group		Significance level
	Mean	*percentage*	*mean*	*Percentage*	
V_1 concepts and link words		YES 87.3 NO 12.7		YES 86.2 NO 13.8	NO (p=0.890)
V_2 nº of concepts $_{used}$	16.35		16.07		NO (p=0.834)
V_3 most inclusive concept		YES 85.4 NO 14.5		YES 75.9 NO 24.1	NO (p=0.275)
V_4 faulty propositions	53.15		54.59		NO (p=0.777)
V_5 coherent hierarchical structure		NO 100		NO 100	NO
V_6 superordination		NO 100		NO 100	NO
V_7 progressive differentation		NONE 100		NONE 100	NO
$V_{8\,l}$ linear sequences		YES 18.2 NO 81.8		YES 17.2 NO 82.8	NO (p=0.915)
V_9 nº cross links	0		0		NO

The following table (see Table 3) describes the baseline and final performance of the treatment group, showing the corresponding means of the quantitative variables, the category percentages of the qualitative variables, and the significance level of the tests performed:

Table 3. Comparison of baseline and final performance of treatment group.

variable	Baseline		Final		Significance level
	Mean	*percentage*	*mean*	*percentage*	
V_1 concepts and link words		YES 87.3 NO 12.7		YES 85.4 NO 14.5	
V_2 nº of concepts used	16.35		22.58		YES. Highly significant (p=0.000)
V_3 most inclusive concept		YES 85.4 NO 14.5		YES 92.7 NO 7.3	
V_4 faulty propositions	53.15		18.67		YES. Highly significant (p=0.000)
V_5 Coherent hierarchical structure		NO 100		YES 29 NO 71	
V_6 superordination		NO 100		YES 41.8 NO 58.2	
V_7 progressive differentiation		NONE 100		HIGH 9.1 SOME 27.3 NONE 63.6	
V_8 linear sequences		YES 18.2 NO 81.8		YES 14.5 NO 85.5	
V_9 nº of cross links	0		1.04		YES. Highly significant (p=0.000)

It is possible to reject the presence of significant variation with respect to the first of the variables considered, that is, the presence of a clear distinction between concepts and link words and an indication of the direction of the relationships between concepts is similar for both observations. The remaining variables nevertheless show significant differences between the baseline and final observations, revealing a clearly positive evolution in the students of the treatment group in the following terms:

- An increase in the number of concepts used in the final maps.
- A greater number of students have clearly identified the most inclusive concept in the final maps.
- A reduction in the percentage share of faulty propositions to total propositions in the final maps.
- The presence in some cases of a coherent hierarchical structure in terms of the inclusivity of the concepts in the final maps.

- The presence in some cases of an example of super-ordination of an inclusive concept, such that some students represent the relationship between the concepts of ***ratio*** and ***proportional relationship*** in their final maps.
- The presence in the final maps of some of the students of complex progressive differentiation of the more inclusive concepts.
- Less presence of linear sequences of relationships between concepts in the final maps.
- An increase in the number of crosslinks in the final maps.

The following table (see Table 4) depicts a final comparison of the study variables between the treatment and control groups. Like the tables above, it shows the corresponding means of the quantitative variables, the category percentages of the qualitative variables, and the significance level of tests performed:

Table 4. Final comparison of the treatment and control groups.

variable	Treatment group		Control group		Significance level
	mean	*percentage*	*mean*	*percentage*	
V_1 concepts and link words		YES 85.4 NO 14.5		YES 93.1 NO 6.9	NO (p=0.303)
V_2 nº of concepts used	22.58		20.72		YES (p=0.022)
V_3 most inclusive concept		YES 92.7 NO 7.3		YES 65.5 NO 34.5	YES (p=0.001)
V_4 faulty propositions	18.67		34.93		YES (p=0.000)
V_5 coherent hierarchical structure		YES 29 NO 71		NO 100	YES (p=0.001)
V_6 superordination		YES 41.8 NO 58.2		NO 100	YES (p=0.000)
V_7 progessive differentiation		HIGH 9.1 SOME 27.3 NONE 63.6		NONE 100	YES (p=0.001)
V_8 linear sequences		YES 14.5 NO 85.5		YES 31 NO 69	YES (p=0.074)
V_9 nº cross links	1.04		0.21		YES (p=0.021)

Again, no significant differences emerge with respect to the first of the variables considered, whereas in terms of the remaining variables the two groups differ significantly by the end of the experiment.

4 Conclusions

The results of the statistical testing of the ML indicators by SPSS reveal statistically significant differences between members of the treatment group and members of the control group in terms of indicators of ML. It is also possible to observe a clearly positive evolution in the students of the treatment group, who report significant differences between the baseline and final observations in terms of an increase in the number of concepts used, a reduction in the percentage share of faulty to total propositions and an increase in the number of cross links, an improvement in the clear identification of the most inclusive concept, a clearer hierarchical arrangement of the concepts coherent with their degree of inclusivity, a reduction in the number of linear sequences and an increase in the number of progressive differentiations integratively reconciled. The only aspect in which no significant difference can be observed is in the first of the variables considered. In other words, both groups are similar at the baseline and at the end of the experiment as far as clarity in the differentiation between concepts and link words and the direction of the relationships between concepts are concerned. This shows that the instructional process was not effective in this respect.

These results, together with the evaluation of the evolution of the students' CMs, show that the delivery in a standard school setting of an innovative IM based on the promotion of positive attitudes, detection of students' initial beliefs and the use of conceptually transparent teaching material, has proved highly successful in helping the treatment group to achieve more meaningful learning on the topic of proportionality. If possible, the experiment would be worth repeating with larger samples.

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CONCEPT MAPS AS A USEFUL INSTRUMENT IN THE TEACHING PRACTICES: AN APPLIED RESEARCH IN THE BIOLOGICAL SCIENCES

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Abstract. This paper presents the results of an applied research experience conducted with a group of undergraduate students in Biological Sciences at the Teaching Practice discipline. The research aimed to surpass pedagogical deficiencies, making use of the concept maps technique, through which it was possible to externalize and share meanings that arise from the reading of supporting texts. The concept maps were discussed, in this paper, through the literal translation of meanings. The results evidenced improvement in the ability of discussing ideas, in group working and in the rebuilding of knowledge.

1 Introduction

When teaching, we have the intention of making the students acquire some meanings that are accepted in the teaching subjects' context, which must be shared among all. In this context, we try to analyze the interaction and the production of meanings in the classroom using a learning sequence, where, through a proposed problem, we explore the vision and the understanding that the students have of a certain idea. Subsequently, it acts as a guide giving the necessary support to the process of externalizing the produced meanings, consequently helping to understanding the whole connection among the biology syllabus looking for a potentially meaningful learning.

To promote meaningful learning, Novak (1997) and Moreira (2006), recommend the educator the use of concept maps as a didactic resource with the purpose of identifying pre-existent meanings in the cognitive structure of the learners that are necessary to the integrative reconciliation and progressive differentiation, processes that identify the learning. Teaching using concept maps becomes important to make a linking between those meanings; it can be useful to achieve this objective and to assess the way it is being achieved.

Another possibility is helping our students to get conscious of what they already know, and to observe the importance of using their knowledge in new shared meanings. This way, the knowledge connects the old to the new one, and according to Gowin and Alvarez (2005), the explicit expressions and the use of key concepts are the simplest and the most convincing ways of negotiating meanings and simplifying the complexity.

The concept maps allow catching the attention related to a group of ideas considered important on which it intends to concentrate in a specific learning task. Besides that, according to Moreira (2006), it is a creative activity, as for from the moment that it acts as a heuristic mechanism, it allows students to build new relations, and consequently, new meanings. The concept maps also favor the externalization of other thoughts present in our students, not easily observable by us teachers (Gowin and Alvarez, 2005).

Therefore, this investigation has as objective to offer moments of reflection from a planned action aiming to overcome the initial educational deficiencies presented by graduates using as resources the intervention, the elaboration of concept maps and discussions about the knowledge externalized and shared by the groups.

2 Research methodology

Understanding that the transformation of the educational practice is only effective from the moment that we extend our capacity of researching the practice itself, and that it occurs through our reflection, its different levels and in the collective in the classroom, (Eliott, 1993 and Moreira, 2002), were the biggest challenges of this research, that had as subject, students of a Biological Sciences undergraduate course. The research had two stages: a diagnosis and later an intervention, consisting of elaboration, discussion and presentation of concept maps by the students. Making use of the interpretation of text: "The Interdisciplinarity in Science: The Genetics Model" by Azevedo (1997), eight maps were elaborated, although in this paper only four are presented, as we intend only to emphasize the discussion around the externalized understanding and shared by the groups.

The maps were numbered by the presentation order and the speeches of the members from each group were recorded, literally written and separated in beginning and interventions, and the interventions were numbered according to the occurrence order. The sequential interventions, in the results' systematization, not only correspond to the number of presentations of each member but also as supplements, reinforcements and justifications that occurred throughout externalizing the meanings by the groups.

3 Results and Discussion

Here we present the results of the text interpretation, through four concept maps, elaborated by four different groups during the intervention period. The workgroup numbering was maintained as the original numbering, for tracking purposes.

3.1 Workgroup 01

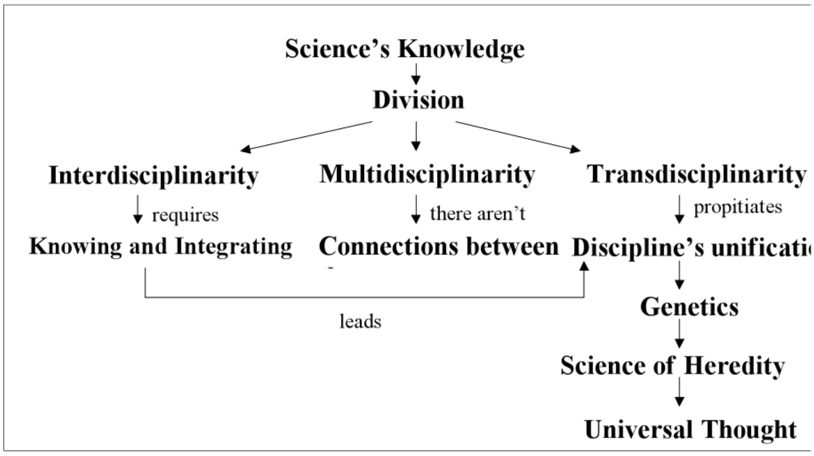

Figure 1. Concept map presented and discussed by group 1.

Beginning: *(...) Teacher, I'm going to explain the map because the girls think we made it wrong, instead of starting with genetics, we started with the Science's knowledge.*

Intervention 1: *I said it isn't wrong, it'll depend on the explanation, isn't it teacher? If we explain it right everybody is going to understand it [...]*

Intervention 2: *We chose eight key words. The main one was the Science's knowledge that we put in first place. The Science can be divided in interdisciplinarity, multidisciplinarity, and transdisciplinarity. In multidisciplinarity there aren't connections between the disciplines. Connections as we know it: geography, mathematics, science [...] The word 'multi' itself already asks: knowing and integrating. But this leads to discipline unification as it is shown here. The unification leads to transdisciplinarity. Here, there should be an arrow pointing there. But we forgot to put it.*

Intervention 3: *We put here beside it the most important one, transdisciplinarity, because it favors the unification of the disciplines that can be seen in genetics. The genetics is the science of heredity, I mean, that thing of passing the characteristics from parents to their children, you know? And, today, it's the most important thing, that's why, we put that it requires universal thoughts. The scientists from all over the world only think about genetics nowadays [...].*

With the presentation of this map, the group tried to explain the constitution of the scientific knowledge through the interdisciplinarity, multidisciplinarity and transdisciplinarity concepts, in the meantime, using a simplistic conceptual hierarchy. It is noticeable a certain difficulty to understanding the text, however, they prioritized the definitions and tried to relate interdisciplinarity to transdisciplinarity, however, without richness in the elaboration of the propositions. During the explanation, it is noticeable the anxiety of the group in demonstrating that the genetics' knowledge can be considered transdisciplinary because through it occurs the unification of several disciplines, favoring a universal thought. In the explanation of the map, it is noticeable that these definitions were valued in the members' speeches.

3.2 Workgroup 04

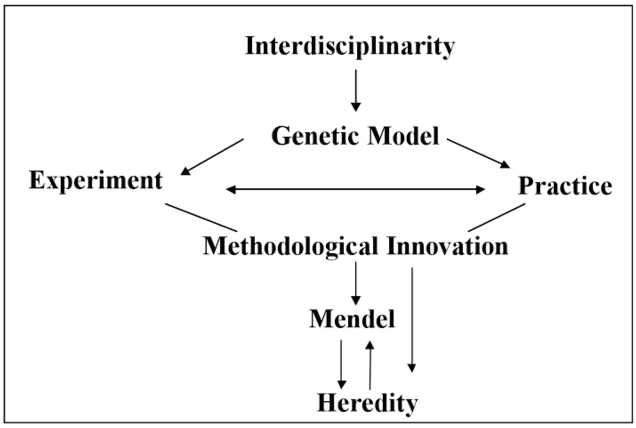

Figure 2. Concept map presented and discussed by group 04.

Beginning: *We chose the seven most important words and put them on the map. But the girls think that the interdisciplinarity is the most important one and it was placed here on the top […].*

Intervention 1: *Now I'm going to explain it: The interdisciplinarity it is found in the genetic model. The genetic model is also composed of experiments and it has practice. Well! Here this arrow indicates not only experiments but also practice; we showed that one leads to the other.*

Intervention 2: *I think nobody understood it right, I'm going to explain it again: The experiments lead to the practical utilization of the genetic model.*

Intervention 3: *The practice and the experiments happen with methodological innovation. This arrow here indicates that the methodological innovation was used by Mendel when he studied heredity. That thing of crossing (Aa), that we study in genetics.*

Intervention 4: *[…] The innovation also improves the heredity study. We understand that interdisciplinarity is important to all of our studies and that we've learned a lot if it is this way […].*

Intervention 5: *We only talked about interdisciplinarity because we didn't understand the transdisciplinarity at the beginning when we read the text. We only understood it when the other groups talked about it. But our map was already done and we didn't want to change it, otherwise it would get ugly.*

The group thought it would be more interesting to use few concepts, that is, only the most important ones, considered as an improvement. They demonstrated insecurity in the construction itself, and this construction was made of a permanent and dynamic movement, being possible to state that there was identification from the group with the developed activity. In the meantime, the relations between the established concepts weren't evidenced by the absence of propositions between the indicative lines.

The map presents a hierarchy with very definite space levels, represented by the arrangement of the evidenced concepts. It is noticeable that the most comprehensive concept is the interdisciplinarity and the subordinates: genetic models, experiments, practice and methodological innovation that inter-relate demonstrating a progressive differentiation of the concepts, such as, the integrated reconciliation between the subordinated concepts.

Another aspect to be considered is the little comprehensiveness that the group worked on the text limiting the knowledge to only two paragraphs of it. When externalizing the learned meanings, all the members gave their contribution, however, in an extroverted way, that wasn't observed on the first presentation.

3.3 Workgroup 05

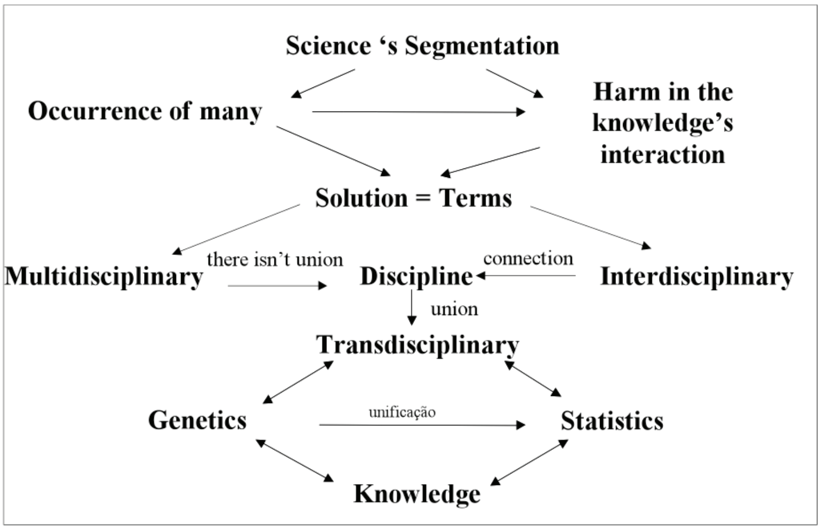

Figure 3. Concept map presented and discussed by group 05.

Beginning: *Reading the text, we reached the conclusion that the author wishes to explain the multidisciplinary, disciplinary and interdisciplinary concepts, and from that on he proposed some questions and examples. The example was genetics, that has a wide necessity of statistics and it looks for an unification. The questions are: the transdisciplinarity and the knowledge where it intends to arrive at.*

Intervention 1: *[...] that's why we make the map this way; we center what the author wanted to explain and above we placed what gave origin to the discussion, which was the segmentation of Science. This contributes to the initiation of several disciplines and brings on losses at the knowledge interaction. From there, a solution was proposed, primarily, the terms pluridisciplinary and interdisciplinary but even so, there was no interaction. Therefore we explain the characteristics of each one of them. Afterward, from the union of the concepts of several disciplines we have the transdisciplinarity, which is very important in the development of Science [...}.*

Intervention 2: *Our map can be read top-down or bottom-up. We believe that doing this way it makes easy to understand and to explain. The arrows are indicating the same direction in the top part of the map. But, at the bottom part, where we speak about transdisciplinarity, the arrows come and go, because we thought that it was necessary and fits better [...].*

Intervention 3: *[...] Coming back to the explanation, the disciplines have their own concepts that when linked can transform the transdisciplinarity. And the transdisciplinarity is important to genetics. I understood that genetics is transdisciplinary, because it links knowledge from several disciplines, for example, the statistics. I think that's it[...].*

The group understood that it is not necessary to make the map in rectangle, round diagrams, etc. However, they didn't make the top organization of the map clearly related to the identification of key concepts. It is noticeable a direct disposition of the proposition that inter-relate giving origin to two concepts represented as synonyms by the equal mathematical expression, included by the group's decision. The central elements used to the structuralism of the proposition on which the new information interacts are: science, disciplines and knowledge, which can be considered super ordered concepts. The new information reflects on the solution to the explanation of the terms multidisciplinary, disciplinary and interdisciplinary (subordinate concept), converging on the transdisciplinarity, a not very inclusive concept.

On the top and the central parts of the map, the indications reflect the relations of cause and effect, while on the lowest part of the map, it is possible to notice the double-handed relations between genetics, transdisciplinarity, statistics and knowledge. Differently, the transdisciplinarity concepts stand out from the others. On the central plan they used the discipline concept that, according to the group, it is the beginning of the whole discussion. By sharing meanings acquired with their class, the different map organization can be justified in a clear and objective way.

3.4 Workgroup 06

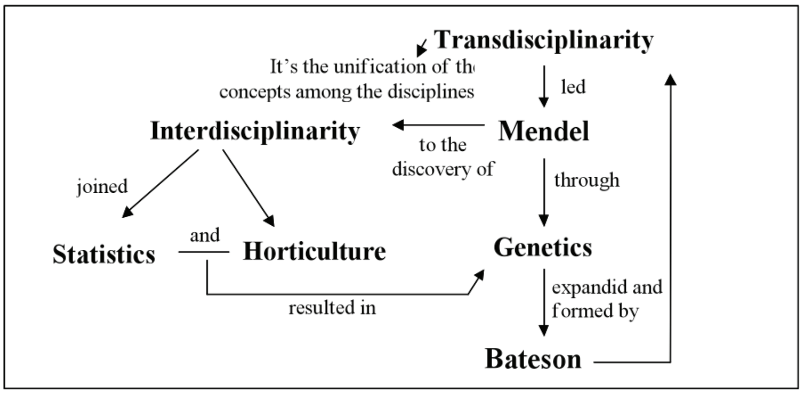

Figure 4. Concept map presented and discussed by group 06.

Beginning: *The group thought the text was very nice, because when we study genetics, we think it's a unique thing and that we only have to know that peas' crossing. Everybody knows what I'm talking about because everybody has already studied genetics at high school and at college. That's why we thought it was nice; we've learned that things aren't exactly like that.*

Intervention 1: *Well! Explaining the map..., we wrote the key word up here. Among the text terms, it's at the end of the text. But we put it first and over the transdisciplinarity that it, as we see it, the unification of concepts between the disciplines and also led Mendel and Bateson to the genetics discovery, it was expanded by Bateson. When Mendel studied the peas he already had the interdisciplinarity concept. He joined statistics and horticulture, which resulted in the study of genetics.*

Intervention 2: *Look! At the end of the map we placed Bateson, which our group had never heard of. Because it was him that studied genetics through the transdisciplinarity. That's why we connected Bateson with this arrow to transdisciplinarity. I think our map was the most correct up to now, wasn't it teacher?*

This group overcame the first difficulty: the elaboration of the map, demonstrating more ability in making diagrams and in the display of the words that resulted in propositions along the arrows. They chose seven key concepts to display and we notice that the chosen concepts are the ones that go through the whole text, suggesting a progressive differentiation, since, the most inclusive concept was displayed in first place and subsequently, it was differentiated in meaningful details. However, it offered few crossed relations, not exploring clearly the subordination and super ordered in all concepts. Nevertheless, making an evaluation, we can say that several implicit meanings were demonstrated and that surely there was learning, since that, new concepts were added to the cognitive structures of the members of this group.

4 Final Considerations

The work with concept maps, in the classroom, requires time and mastery of the elaboration process; therefore, it is up to the teacher to learn about teaching techniques and its usage. And, when teaching, the teacher not only acquires and but also develops several abilities that are shared throughout the educational practice, besides that, the work with maps needs to happen at the same time as the concepts' learning, considering that, some groups demonstrated difficulties in recognition and distinction of the terms that identify a concept.

The greatest challenge to the Teaching Practice Teacher is helping the graduate to use, in a conscious, productive and rational way their potential thoughts, which is, leading the student to think, as well as, becoming conscious of the learning strategies that turn to building and rebuilding the most important concepts of its teaching subject. This way, the earlier this process begins, the most effective the result will be.

Besides that, the teacher must be aware of the development of attitudes and values, since that, the critics to the group work by the others, must be well grounded in ethics, which is, respecting, being sympathetic, through dialogues, and being fair in judgment. The social relationships among the groups, in this case, needs to be well established and not imposed, because the activity requires informality, being ready to present the paper and receiving critics. Nevertheless, we can state that this teaching/learning strategy amplifies the capacity of interpretations and rebuilding texts.

The work with concept maps favors the learning process and stimulates the student to put the acquired knowledge into practice in other situations or in other disciplines. As well as, it can be misunderstood as a teacher's escape not to give classes, when the student doesn't understand the role of the teacher as helper on the teaching-learning process. Another question to be reconsidered is the fact that the students take, or not, into consideration the elaboration of the concept maps as an educational resource, because there isn't right or wrong, "behaviorist dichotomy" to be overcome by the teacher and the student during the Teaching Practice.

As for the concept maps' diagrams, the challenge is demystify the hierarchy question, seeing that, according to the student's culture, hierarchy is always from the top to the lowest part and not inter-directional that favors thinking of the maps as a flow organization chart, making difficult the crossed relations among the definite concepts in its elaboration.

Another question the break of the paradigm that the map must get rid of beauty, because the beauty is always well done, outlined, divided in diagrams, colored, with well defined dimensions and it is the best and not the one that demonstrates relations with several dimensions, considered intelligent.

It is noticeable that even elaborating several maps, some group was loyal to the initial diagrams as it was a registered mark from the group and with their own characteristics. Another fact to be considered is the constant questioning about the necessity of inserting key words, that lead to the formation of propositions as, for example: *...If the map is self-explanatory why are we supposed to draw these arrows? Couldn't we just mention it?* Reading the text, on this case, became superficial with the only objective of identifying the most important concepts.

A deeper analysis of the presented concept maps requires a detailed evaluation from the several stages and elaboration, so that it can be stated with sure that during the intervention occurred progressive differentiation and the integrated reconciliation, processes that permit to identify the occurrence of a meaningful learning.

The continuation of this investigation, with the graduates in the Biological Sciences, depends on feedback sessions so that the groups can reanalyze the concepts placed in the center of the discussion and at the same time, the group (teacher and students) evaluate the instrument used and share new meanings, identifying mistakes and offering resources of mutual help.

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CONCEPT MAPS AS MEANINGFUL LEARNING TOOLS IN A WEB–BASED CHEMISTRY MATERIAL

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Abstract. This paper presents a web-based learning material and its design process which goal is to support meaningful chemistry learning in the context of insect chemistry through concept maps. This material was designed based on the results of a four phases of a design research process: (i) a theoretical problem analysis phase, (ii) a development of a material phase, (iii) an evaluation phase, and (iv) a further development phase. This material was found useful primarily for high-school chemistry instruction. The results show that concept maps were an effective learning aid and navigation tool in web-based learning environment, according to chemistry teachers.

1 Introduction

It is often difficult to find relevant information from web pages. A traditional web material that consists of large numbers of web pages can sometimes be difficult to use for educational purposes. Students may find the structure of the material unclear. In addition, the structural complexity also affects learning motivation, which is inconsistent with Ausubel's theory of meaningful learning (Ausubel, 1968).

Using ICT in chemistry education is still rather infrequent at the basic level in Finland and also globally (Meisalo et al., 2007). Especially, chemistry teachers wish more useful web-page materials. Web materials offer several ways to support meaningful chemistry learning, for example, new opportunities to increase communication and interaction among students, more ways to seek and share scientific information, new kinds of educational materials and tools, which are also easy to bring into the classroom via the web (Aksela, 2005).

This material was created primarily for high-school chemistry teachers in Finland through a design research process (Edelson, 2002). The material has been partly translated to English (a goal is converting it entirely to English). The material approaches chemistry from an insect chemistry context, particularly semiochemicals, pigments, and honey bee that is a full of interesting chemistry.

2 Concept maps in chemistry

Chemistry is often full of abstract concepts, resulting from the complex nature of this science. It may lead to extensive misconceptions among students (Gabel, 1999). It is also a common problem in chemistry that even if students do well in examinations, they still may fail in solving basic textbook problems, which is a sing of rote learning (Pendley et al., 1994).

It is important to find various interesting ways that can lead toward meaningful chemistry learning. One way to accomplish this, is to apply Ausubel's theory of meaningful learning. Concept maps were devised as a device of meaningful learning, which can be regarded as the opposite of rote learning. Concept maps are graphical teaching, learning, evaluation and presentation tools (Novak 1998; Novak & Gowin, 1984).

In chemistry, the use of concept maps has been widely investigated. According to several studies (e.g. Cardellini, 2004; Francisco et al., 2002; Markow & Lonning, 1998; Nicoll et al., 2001; Osman Nafiz, 2008; Pendley et al., 1994; Regis et al., 1996; Stensvold & Wilson, 1992), concept maps help chemistry learning both in classrooms and in laboratories. According to Francisco et al. (2002) and Nicoll et al. (2001), concept maps are a useful learning tool in chemistry. Concept maps can improve understanding of chemical concepts and help build connections among abstract concepts. Concept maps can also be used as a misconception-correction tool. Concept maps bind concepts with linking words that help students see connections among them and organizes the knowledge hierarchically, based on scientific knowledge. (Francisco et al., 2002; Nicoll et al., 2001)

Markow & Lonning (1998) and Osman Nafiz (2008) studied the use of concept maps in laboratory activity. They both reported that pre- and post-laboratory concept maps made easier for students to understand concepts related to the laboratory work. Sometimes those concepts remain unconnected, because the laboratory work itself demands much concentration. (Markow & Lonning, 1998; Osman Nafiz, 2008). There is also evidence that concept maps reduce students' attentions to distractions in laboratory and improve understanding of procedures and directions used in the laboratory work. (Stensvold & Wilson, 1992)

3 Concept maps in web materials

Traditional web pages are the major technique used for organizing information and browsing in the internet. Traditional web pages are often just printed pages, which can be difficult to organize if web materials consist of large number of pages. When the content of the material is hierarchical, concept maps offers a meaningful and efficient way to organize the information (Carnot et al., 2001).

Little research has been conducted to investigate how concept maps work as navigational and learning tools in a web-based learning environment. Earlier study (Carnot et al., 2001) made from the area focused on comparing searching results between traditional web pages and concept hyper maps. The study covered searching efficiency and searching accurancy. It also took into account differences between meaningul and rote learners. According to study, both meaningful and rote learners attain better searching outcomes and searching efficiency through concept hyper maps, but meaningful learners gain a little more benefit from concept maps than rote learners. (Carnot et al., 2001)

4 Design research

This study was conducted as a design research (Edelson, 2002). The main research question is: *What kind of a web-based learning environment can best support meaningful chemistry learning through concept maps?*

The research consisted of four phases: (i) a theoretical problem analysis through a literature analysis, (ii) a development of material phase, (iii) an evaluation phase, and (iv) further development of the material. The purpose of the evaluation phase was to investigate how concept maps can serve as a component of web-based material.

As a part of theoretical problem analysis a literature analysis by using a content analysis was proceeded. It included 24 Finnish high-school chemistry text books. After the results of the literature analysis, the content of the material was limited to semiochemicals, pigments and one insect example (honey bee).

The material was designed according to Jonassen's (1999) criterions on meaningful web-based learning environment. The material includes contextual, constructive and active features. The objective to produce an extensive insect chemistry material bank for meaningful learning purposes was kept in mind at all times.

Evaluation was executed in the autumn 2007. Research sample consisted of 17 experienced chemisty teachers. Questionnaires were delivered to respondents. They had time to acquaint oneself with the material and fill up the forms. 76 % of the teachers had been teaching over 15 years. 59 % of the teachers found generally working in the web-based learning environment pleasant (see Table 1). Most of them thought, that also students enjoy working in web. Teachers opinions towards concept maps were more divided. Only 18 % used concept maps as teaching tools, 41 % used concept maps as learning tools and 65 % of the teachers thought that concept maps improve learning.

Proposition	Answer (%)		
Working in a web-based learning environment is pleasant.	Pleasant	Unpleasant	Can't say
	59	0	41
I think students enjoy to study in a web-based learning environment	Pleasant	Unpleasant	Can't say
	76	0	24
I use a web-based learning environment	Often	Seldom	Never
	35	47	18
I use web-based materials in my teaching.	Often	Seldom	Never
	35	59	6
I use concept maps as teaching tools.	Often	Seldom	Never
	18	58	24
I use concept maps as learning tools.	Yes	No	Can't say
	41	41	18
Concept maps improve learning.	Yes	No	Can't say
	65	0	35

Table 1. Chemistry teachers answers, % (N=17).

The results of the evaluation were analyzed. Further developments were made based on the results and feedback. The final material is available online at http://www.helsinki.fi/kemia/opettaja/aineistot/hyonteistenkemiaa/index.htm (in Finnish).

5 Results

5.1 The designed Web material

The idea was to design the structure of the web material to support meaningful chemistry learning through an easy navigation process. The solution was to create the navigation system from concept maps. The concept maps were made by *CmapTools* program (see http://cmap.ihmc.us). The *CmapTools* program was selected, because it enables, for example diverse link resource possibilities, example animations, pictures and documents. The student navigation process is restricted by links, which makes it impossible to get lost in the material.

The web material consists of four map pages (see Figure 1 and Figure 2), eight concept map pages (see Figure 3) and 11 web pages (see Figure 4). The map pages help students sketch the structure of the material and form the basic navigation routes. Navigation is restricted to one branch (semiochemicals, pigments, bees or tasks) at a time (see Figure 1 and 2), which helps students navigation and orginizes extensive material.

The level of information in insect chemistry becomes deeper after every stage. A concept map page (see Figure 3) gives an example to the content of the web page (see Figure 4). The purpose of the concept map page is to help students to preorganize the knowledge of the web page. Concept maps provide students a challenge to construct their own mental models from the content of the upcoming web page. Concept map pages can also be suitable for fast recap during the returning from the web page level, where the chemistry level is deepest. Making the learning easier for students, web pages include animations and several interactive molecular models, which help students to understand the chemical phenomena in question.

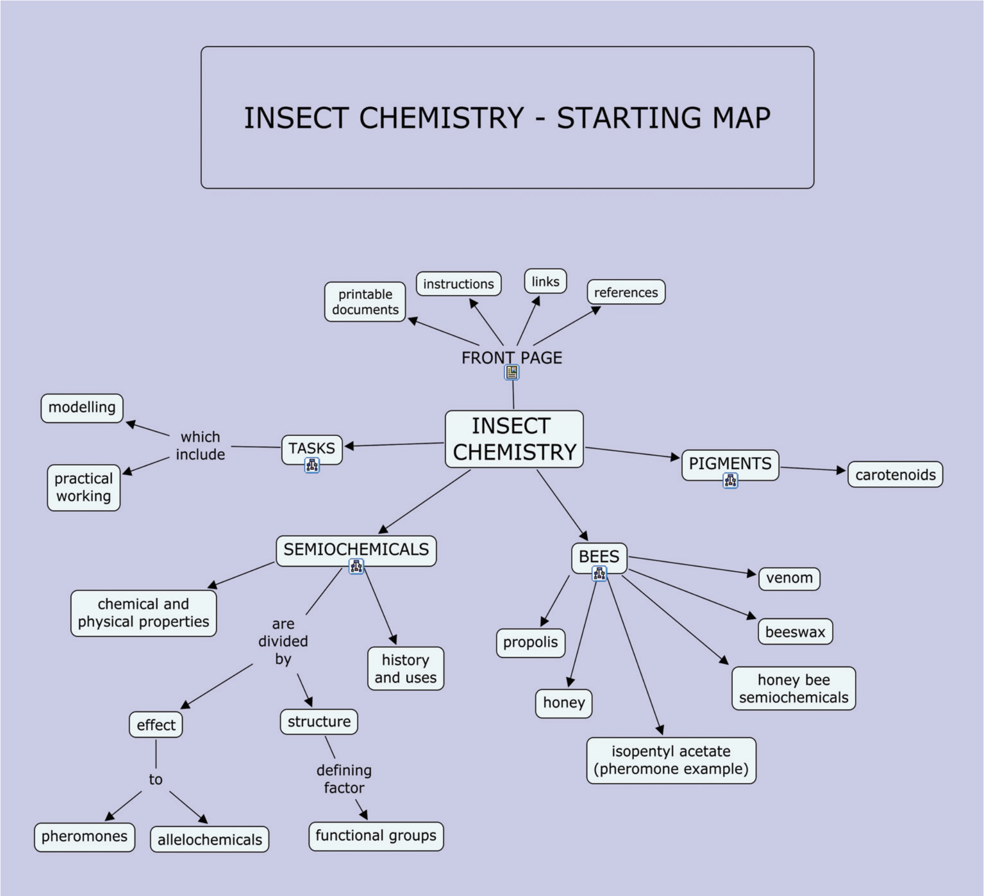

Figure 1. A Starting map of Insect chemistry (a table of contents).

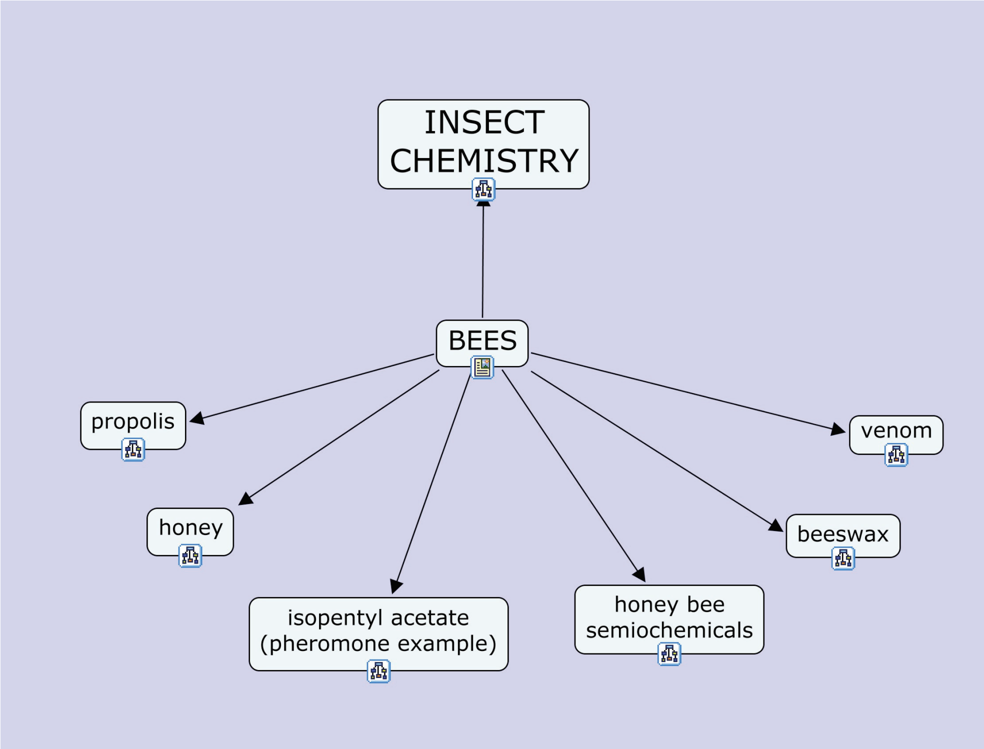

Figure 2. A Map page of Bees.

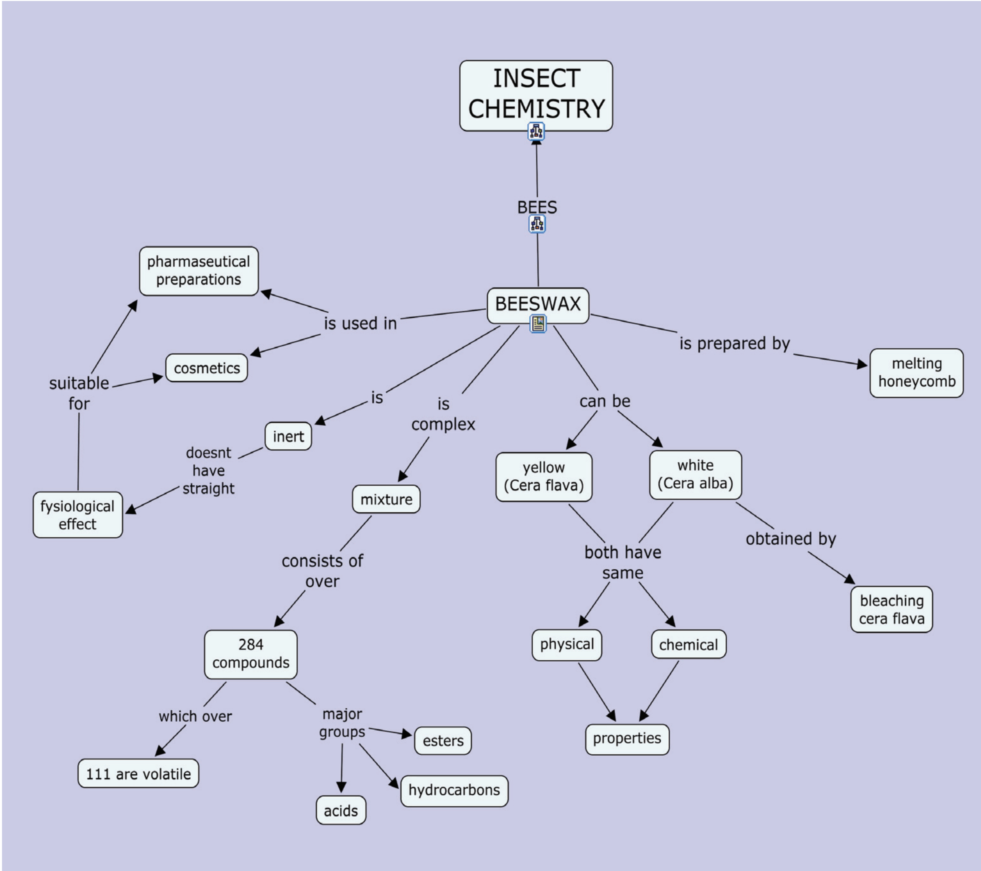

Figure 3. A Concept map page of Beeswax.

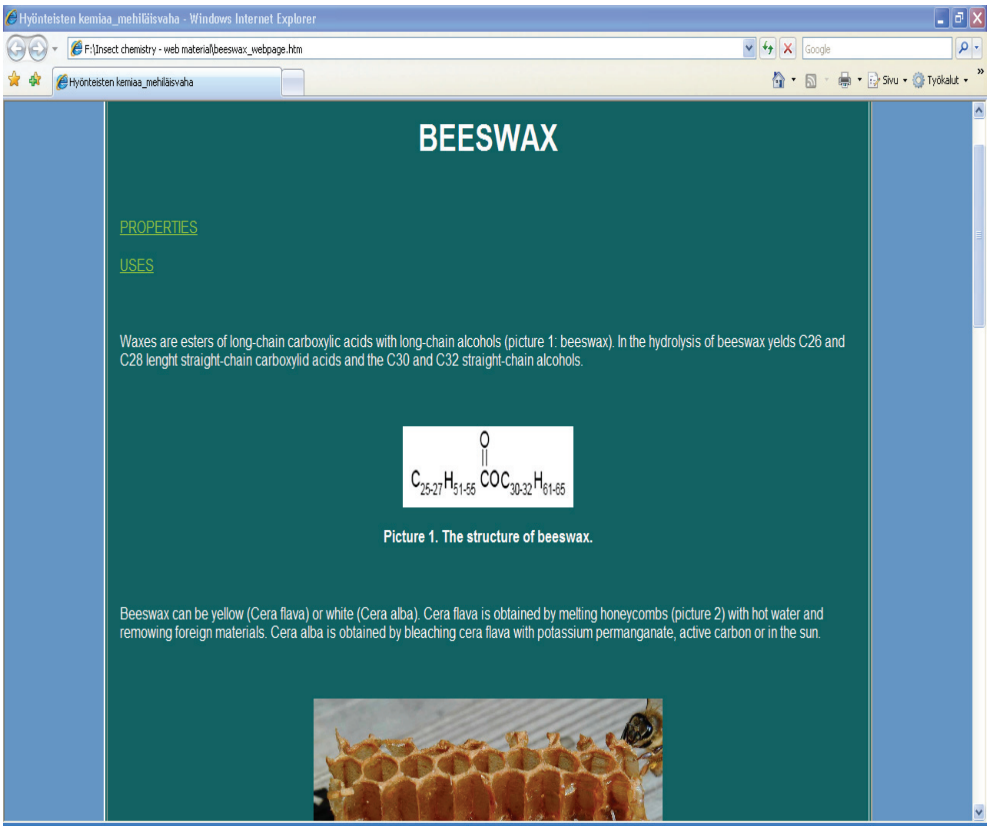

Figure 4. A Web page of Beeswax.

5.2 The results of evaluation phase

The material was evaluated using a five-point Likert scale (1=bad, 2=fair, 3=adequate, 4=good and 5=excellent).

The material was useful among the chemistry teachers. All averages for questions are quite high (see Table 2). According to 71 % of the teachers (at least good (=4) in the Likert scale) the used concept maps clarified the structure of the material (average 3,8). 18 % of the teachers (1 or 2 in the Likert scale) felt that the material was too extensive and there were too much concept maps. 88 % of the respondents felt that the concept maps made the learning more efficient (4 or 5 in the Likert scale).

However, concept maps' usability as a navigation tool divided opinions. Overall, the respodents felt that the *Cmap* hyper maps were a suitable navigation tool (average 3,6), but almost 18 % (1 or 2 in the Likert scale) felt that the Cmap hyper maps were difficult to navigate. 18 % felt that the two clicks, which are needed to perform in order to get through the link resources, was an unsatisfactory feature and made the navigation difficult.

Question	**Frequency**					**Average**
	1	**2**	**3**	**4**	**5**	
How do concept maps effect to the structure in the topic?	1	2	2	6	6	3,8
How do concept maps work as a learning tool?	0	0	2	10	5	4,2
How do concept maps work as a navigation tool?	1	2	3	7	4	3,6

Table 2. Results of the evaluation phase, (N=17).

Some open comments of the teachers:

Positive:

- *"The system is clear and educational."*
- *"Versatile, clear and easy to navigate."*
- *"I feel like the learning becomes more effective."*
- *"Practical and interesting way to organize knowledge"*
- *"Concept maps clarified the structure"*

Negative:

- *"There were too much concept maps. I did not get the whole picture."*
- *"Cmap page is difficult to navigate."*
- *"The material is difficult to use just in chemistry teaching because of the biological side. Maybe it is also too extensive."*
- *"Concept maps have a bad reputation."*
- *"There is too much concept maps and too little time to explore the material."*

6 Summary and conclusions

A useful web-based learning material to support meaningful chemistry learning in the context of insect chemistry through concept maps was designed. Overall, the material was well accepted among the respondents. 71 % of the chemistry teachers felt that concept maps clarified the structure of the material, and 65 % replied that concept maps are an excellent or a good navigation tool for web material. Also Carnot et al., (2001) reported that hyper concept maps are a proper browsing and knowledge organizing tool in www environment.

Only 18 % felt that concept maps are not a suitable navigation tool for web material. Negative freedback concerning the browsing aspects considered about hyper cmaps made with *CmapTools* -program. Some of the teachers found them hard to use because of the double clicks, which are needed to perform in order to get through the link resources. But then, double clicks are a part of the programs diverse link resource properties, which influenced to the program selection in the first place.

During the answering process, chemistry teachers' opinions towards concept maps changed. Before getting familiar with the material, only 65 % thought that concept maps improve learning. After working with the material, 88 % of the teachers felt that concept maps made chemistry learning efficient (4 or 5 in the Likert scale). Results correlates with other researches made from the same area (e.g. Cardellini, 2004; Francisco et al., 2002; Markow & Lonning, 1998; Nicoll et al., 2001; Osman Nafiz, 2008; Pendley et al., 1994; Regis et al., 1996; Stensvold & Wilson, 1992).

The small sample size (N=17) is a weakness in this study. It is also notable that some of the respondents felt that the material was too extensive for full exploring and evaluation. But then, the material was supposed to be extensive because the objective of the material was to serve as an extensive and diverse insect chemistry material bank for chemistry teachers.

In the future, it is important to develop the material more through research. It is important to study how teachers use the material, and how students experience on it. There should also be studied, how the material supports meaningful chemistry learning. The content of the material can also be limited in a way so, that it can be used as teaching material in high schools for a specific chemistry area. According the literature analysis, the area could be for example organic chemistry related to semiochemicals. It is important that the content fits under the goals of the the Finnish curricula. At this point, the results are encouraging and it justifies further studies in this area.

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CONCEPT MAPS AS RESEARCH TOOL IN MATHEMATICS EDUCATION

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Abstract. Using concept maps as research tools in different ways has been found productive in a longitudinal study on student teachers' development of mathematical concepts. Maps were used both in a priori analyses of groups of concepts, that are part of content in courses, and as a tool for students to express their conceptions of functions, equations and so on. Examples of one student's maps drawn at three different occasions over a time period of 15 months reveal that the concept image is developing over time although the student is not studying mathematics or working with mathematics. The slow development of concepts and need for maturation and cognitive processes to take place is illustrated by the examples. Some outcomes of the study are mentioned and indicate further use of concept maps. Mathematics teachers need for development of a professional language is one important result and a model for mathematics teacher education seen as the development of the professional identity another result.

1 Introduction

Longstanding work with mathematics teacher education has stimulated my curiosity in how student teachers develop concepts in mathematics and mathematics education. In 1996 a new teacher education programme started in Kristianstad University for prospective teachers in mathematics and science for school years 4-9. I led the work with creating the mathematics courses for this programme (Grevholm, 1998), building on all my earlier knowledge and experience from teacher education. Consequently, I was eager to follow the development of the education and its outcomes. I decided to carry out a longitudinal research study and in this try to focus on student teachers' conceptual development, as I (as many other researchers) had noticed how important this is for the in depth learning. In Sweden no such study was conducted earlier.

It is complicated to do research on students' conceptual development as the concepts an individual holds are not open to direct observation. They can be studied only indirectly through actions, statements or answers given by the individual student. Thus I started out to collect all data that could possibly help me to observe students' conceptual development. Soon after I had started the data collection, Joseph Novak came to visit our department. When he heard about my study he tried to convince me that it should be productive to use concept maps. At the beginning I hesitated. From the examples I saw of biological concepts it was obvious that objects and events could be studied and observations formulated in knowledge propositions and represented in concept maps. You could for example study a plant and describe the development. But I did not find it possible to look at 'objects and events', when it came to mathematics. All mathematical concepts are abstract. It took me some time to reflect more closely on the differences between concepts in science and in mathematics. After a while I came to the conclusion that objects in mathematics can mean the mathematical objects like numbers, shapes, equations, functions, and expressions and so on. And events can be seen as the operations, processes, constructions or actions we make with these objects. After this interpretation it became clear to me how useful the concept maps could be also in my study. Based on experiences from the study, the use of concept maps as a tool for research on development of mathematical concepts is explored and discussed in this paper.

In this paper I want to explore the use of concept maps in mathematics education research and try to answer the questions:

- Can concept maps as a tool in research contribute to our understanding of students' conceptual development in mathematics?
- In what ways can concept maps be useful?

2 Theoretical background

Theories in mathematics education deal with phenomena such as meaningful learning versus rote learning, conceptual knowledge or procedural knowledge, mathematical phenomena seen as procedures or objects, and conceptual change and development as an important part of learning (Ausubel, 1963, 2001; Ausubel, Novak & Hanesian, 1978; Hiebert & Lefevre, 1986; Sfard, 1991; Tall & Vinner, 1981). In several of these theories mathematical concepts and the development of concepts are crucial.

Knowledge construction is a complex product of the human capacity to build meaning, cultural context, and evolutionary changes in relevant knowledge structures and tools for acquiring new knowledge, according to Novak (1993). Novak claims that concepts play a central role in both psychology of learning and in epistemology. In his Human constructivism Novak (1993) builds on Ausubel's assimilation theory of learning to describe the process by which humans engage in meaningful learning. Two key ideas in assimilation theory are *progressive differentiation* and *integrative reconciliation*. Novak explains that as new concepts are linked nonarbitrarily to an individual's cognitive structure progressive differentiation occurs. The integrative reconciliation occurs when groups of concepts are seen in new relationships.

Hiebert and Lefevre (1986) devoted much interest to the discussion of conceptual and procedural knowledge. Conceptual knowledge is equated with connected networks. Conceptual knowledge is knowledge that is rich in relationships. Procedural knowledge is a sequence of actions. Sfard's reification theory (1991) concerns mathematical phenomena seen as processes or as objects. In an often quoted paper Tall and Vinner (1981) discussed *concept image* and *concept definition*. They note that many concepts are not formally defined at all but we learn to recognise them by experience and usage in appropriate contexts. After some time the concept may be refined in its meaning and interpreted with increasing subtlety. They continue:

> *Usually in this process the concept is given a symbol or name which enables it to be communicated and aids in its mental manipulation. But the total cognitive structure which colours the meaning of the concept is far greater than the evocation of a single symbol. It is more than any mental picture, be it pictorial, symbolic or otherwise. During the mental processes of recalling and manipulating a concept, many associated processes are brought into play consciously and unconsciously affecting usage and meaning (p. 152).*

At this stage they introduce the term concept image (held by the individual) to describe the total cognitive structure that is associated with the concept. The concept image is personal and changes when the person meets new stimuli and matures. Tall and Vinner (1981) also make a difference between the formal concept definition (accepted by the mathematical community) and the personal concept definition (the words the student uses for his own explanation).

Other researchers, such as Vollrath (1994), have discussed the meaning and development of concepts. He claimed that the student reaches stages of understanding and that there is no final understanding. Ausubel (1963) contrasts meaningful learning to rote learning, where meaningful learning results in the creation and assimilation of new knowledge structures. In many of the theories there seems to be a continuum from lower quality learning to higher quality learning, where higher quality often includes concept development. The theories can be seen as different ways to model the quality of learning and how it evolves.

Joseph Novak (Novak & Gowin, 1984) has introduced *concept maps* as a cognitive tool and as a research tool. In his case the researcher drew the maps in order to give a concentrated representation of what an interviewee answered (Novak, 1998). The map is used for data reduction and concentration of content. From his writings (Novak, 1998) it is well known how he defines a concept and what he means by a concept map. In Novak's maps it is important that the map is built of knowledge propositions. The nodes that contain concepts should be connected by linking words to form propositions, which represent knowledge sentences. Normally the map is also hierarchical. The map can be seen as a picture or image that the learner chooses to draw from what he experiences as the mental representation of his knowledge. A map drawn by a student is time-dependent, individual and dynamic.

In research literature many different sorts of concept maps have been introduced (see for example Williams, 1998). A concept map differs from for example a mind map, which is a looser construction and does not necessarily show how the learner wants to draw his knowledge representation. A spider web map has no hierarchical character. In this paper I use Novak's definition of concept and concept map.

Research using concept maps as a tool

Williams (1998) used concept maps to assess the conceptual knowledge of function. She studied concept maps drawn by students and professors of mathematics and compared them. Her dissertation was based on that work and she claims that "Concept maps are a direct method of looking at the organization and structure of an individual's knowledge..." (p. 414). This strong claim can be questioned and she modifies herself in the conclusions. There she states (p. 420): "The degree to which concept maps describe a person's mental representations is, of course, impossible to know." But her final conclusions are important:

The analysis also provided information about students' understanding that is not readily gained from traditional paper-and-pen tests. Concept maps therefore, provide important information about conceptual understanding and can play a useful role in the mathematics researcher's repertoire of tools. (p. 420)

Novak and his colleagues used concept maps in many studies and argue strongly for their potential in research and in learning (Novak, 1985, 1993, 1998). In her master's research, conducted at Samoa University, Afamasaga-Fuatai (1998) used concept maps. Her research shows that students found concept maps useful in their learning and understanding of mathematics. It helped in systematic analysis of a topic for the interconnections between relevant concepts and procedures, and facilitated problem solving. There are other studies available using concept maps in research (for references see Williams, 1998 and McGowen & Tall, 1999), studies mainly in science didactics but also in mathematics didactics. One of my doctoral students have replicated parts of my study and used concept maps starting from mathematical expressions instead of concepts (Hansson, 2006).

3 The use of concept maps in the research study of student teachers' mathematics

There are different ways to use concept maps and as a tool in research I first used it in an a priori analysis (Artigue, 2002) of the expected learning of students in their course. For example I drew a map of the concept *fractions* (with 25 nodes and 30 links), where I tried to include all the important features about fractions that I consider crucial in the course the student teachers were going to study. Later, after the students had answered a questionnaire about the course in number theory, I used a concept map in the analysis for data reduction on the answers about fractions, by drawing all alternative answers given by the students and the links they proposed. In comparing my a priori map with the map constructed by the students' answers I could see what parts of the expected exposed learning that had taken place and not.

Another way I used the maps, repeatedly over time to follow the conceptual development, was to let students express their view of a concept. Below I will show some examples of the data it produced and discuss what results one can get from it. First I need to say something short about the study in which the maps were used.

4 Methods in the study of student teachers' concept development in mathematics

The method used in the study drawn upon here is mainly qualitative investigation of data from different types of documentation of students' cognitive development during a teacher preparation program. Concept maps are used as a tool both for analysing the content of the teacher education to find the fundamental concepts, to investigate students' answers in questionnaires and interviews, and for the students to express a picture of their current concept structure.

The overarching questions posed are phrased: How are the studies of mathematics and mathematics education influencing student teachers' development of concepts in these areas? How do student teachers' perceptions of and attitudes to mathematics change during the education? What impact does the development of concepts have for the learning outcome and for the students' perception of their own learning? The studied group consisted of 48 student teachers studying to become compulsory school teachers in mathematics and science for school years 4-9. I have reported on this study elsewhere (Grevholm, 1999, 2000, 2002, 2003ab, 2004, 2005, 2006) and here I am only going to discuss the use of concept maps as a tool in research.

Students' concepts are not open to direct study by the researcher. They have to be observed in an indirect way and often only in fragments. Some researchers argue that concepts should be studied through their appearance in students' actions. This is however time-consuming and a difficult process. Here questionnaires were the first attempt to get an image of students' conceptions, followed by interviews based on the answers given. The impression was that far too little of what students carry in their heads about the concept was revealed in this way. I was convinced that students could expose more to me about their concept image. At this stage concept maps were introduced as the answer form for students. As will be shown below a much richer material was retrieved in this way and substantial knowledge about how students express their mental structures through maps became available. By having students draw maps at several times with long intervals the development over time of the structures could be studied. With the examples below I want to illustrate that if concept maps are used as a tool for research, the findings differ in a positive way from results from questionnaires and interviews.

5 Examples of collected data

In the investigation an example of the outcome of the questionnaires could look like this. To the question ‘What do you mean by a function?’ Lina, one of the students, answered before and after the course in function theory (calculus):

1) – *y* is depending on how big *x* is. There is an infinite number of answers as you can vary *x* (January 1999).
2) – for example *y*=k*x*+m. *y* is here a function of *x*. So y is depending on the *x*-value. You can illustrate a function graphically (March 1999).

At both occasions Lina holds on to the idea that y is depending on *x*. In the first answer she talks about answers to the function, which may indicate that she perceives each calculation of the *y*-value as an answer to a problem. She cannot see a function as an object (Sfard, 1991). In the second answer she gives an example, the simplest possible function she has worked with, the linear function, although in a general form. She also adds the information that one can illustrate a function graphically. In the second answer she actually reveals more than in the first answer.

Still both these answers give very little information about the mental representation or concept image (Tall & Vinner, 1981) she has of the concept function. I was convinced that the student could show me more of her knowledge structures than these short sentences. The drawing of concept maps was already familiar to the students from other subjects in their education. Still I was aware of the fact that it is very demanding to try to draw a concept map of your own knowledge.

At the end of the course in calculus (five weeks in the sixth term of the 4.5 years long education programme) Lina together with one fellow student drew a map of the concept function. The task given was to individually draw one map of function and one of equation. The students did not follow the instructions. The map is not an individual map and it is a map of both equation and function in the same picture. From function there are seven links to equality, inequality, variables, straight line, proportionality, coordinate system and rule or instruction for calculation. Coordinate system is linked to coordinates and to x-axis and y-axis, which is an example of rather trivial facts often present in novice’s maps (Williams, 1998). The map is consistent with Lina's answers in the questionnaires but contains more.

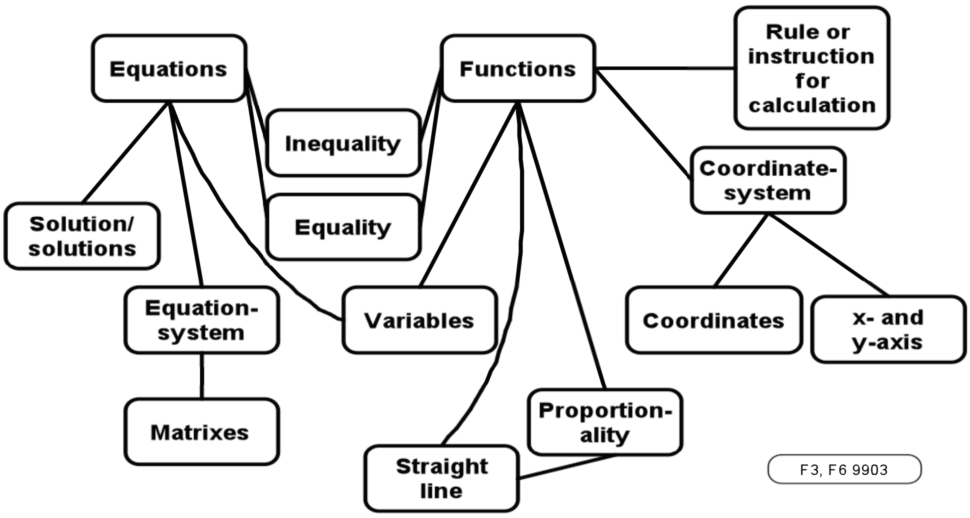

Figure 1. The first concept map of function (and equation) drawn by Lina and a fellow student in March 1999.

Nine months after the first map was drawn I met Lina again for an interview and she had been asked to draw a second map without looking at the first one (which resided with me). In the meantime Lina had studied other subjects than mathematics and she had not worked with her mathematics in organised studies at all. In spite of this it is obvious that her second map is richer than the first one. It contains more concepts and more propositions. She has removed the concepts straight line and proportionality and has added on domain, range, the properties even or odd, graph, primitive function and integral. In adding the properties she shows that progressive differentiation in her concept picture has taken place (Novak, 1993). She removes variables and co-ordinates and writes *x* and *y* instead. In the first map she talks about a rule or instruction for calculation. In the second map she gives a definition instead. She also explains that the same *y*-value can be related to different *x*-values. Still there are several unclear links in her map. Why does she connect domain and range in different ways? Why are *x* and *y* not connected to the box 'a coordinate system'?

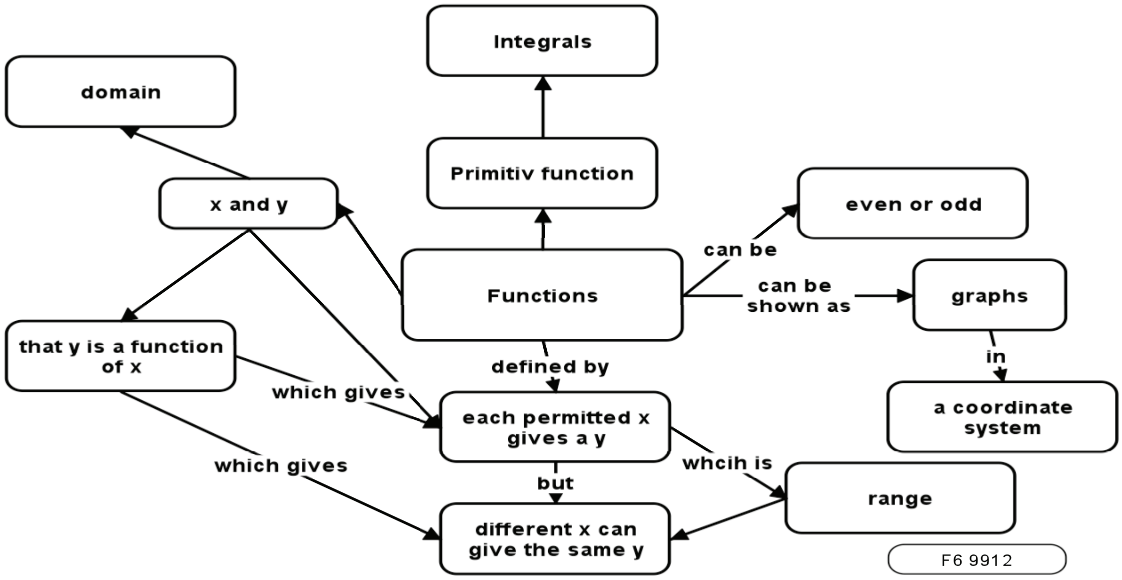

Figure 2. The second concept map of function drawn by Lina in December 1999.

Although she did not study mathematics from March 99 to December 99, changes in her concept map have taken place during that time. What the map shows is probably knowledge that has been learnt in a meaningful way (Ausubel, 1963). Otherwise it would have been forgotten and not retrievable after such a long time. Above is the second and below the third map drawn by Lina.

The third map was drawn six months after the second one, again without access to the first and second ones and without Lina having had any mathematics studies in the meantime. Again the third map is still richer than the two earlier ones. In the third map she has linked range and domain to the definition of function in a better structured way than before. This is an example of integrative reconciliation in the concept structure (Novak, 1993). Instead of talking about graphs she now mentions curves and gives a number of possible properties for them.

Lina adds table of values and links it to coordinate system and to this node she also adds a third axis, the *z*-axis. She returns to linear function, which she had in the first map (and excluded in the second) as straight line and explains how it can be written as y=kx+m. She also explains the meaning of k and m. Another example of progressive differentiation is that she in addition to linear function also mentions other function classes as polynomial, rational, power, exponential and trigonometric functions, and so on. Williams (1998) noted that the experts in her study used a grouping that referred to classes of common types of functions, mentioning terms as exponential, polynomial, trigonometric and logarithmic. Thus here Lina's map has a feature that is typical for experts' maps.

Lina holds on to the nodes primitive function and integration and adds differentiated. One link seems to be not so well expressed: 'Functions can be solved graphically or....' It is not clear what she means here. It can be a mix up with solutions of equations but it can also be that she is thinking of problem solving with the aid of the graph of the function. This last proposition is an example of the student's lack of professional language, which many of the maps illustrate (Grevholm, 2004). While her second map has twelve nodes the third one has 25, more than twice as many. It strongly illustrates the progressive differentiation her function concept has undergone.

The maps were drawn over a period of 15 months where the student had no teaching of mathematics. But the maps show that great changes occur nevertheless. It seems as if the conceptual structure, the concept image, that the student is able to recall is getting richer as time goes by. One can of course argue that she is learning through repeated drawing of maps. This argument does not hold as can be seen by giving students the same mathematical problem again. There is normally no or little improvement in results even if the student has solved the problem once before. And the students did not keep the map that was once drawn and so could not rehearse it before drawing a new one.

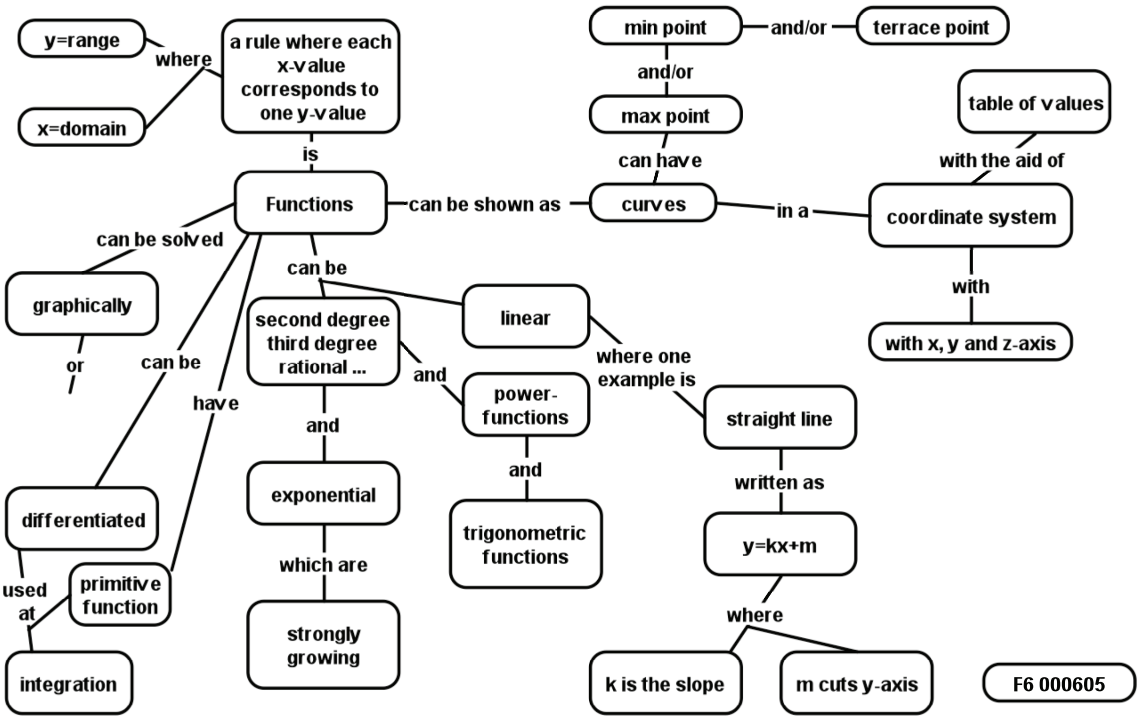

Figure 3. The third concept map of function drawn by Lina in June 2000.

The example of maps of one student given here is a typical one. The kind of development over time shown in the maps of Lina is not special in any way. The maps are very individual, each student has her way of drawing and is true to the model and design. The language in the maps reveals much about the student's ability to use the concepts involved in discussions (Grevholm, 2004). Lina's three concept maps illustrates Vollrath's claim (1994) that "the student reaches stages of understanding and that there is no final understanding". The conceptual structure undergoes changes over time and is dynamical and time-dependent. The maps indicate that we are dealing with a slow development and maybe as researchers we are sometimes too eager and do not wait for the concept development to take place and for the student to reach different stages?

6 Why are concepts maps rewarding as research tools?

What the researcher can learn about students' concept development from answers in a questionnaire and from the drawing of concept maps seems to be different. The verbal answers give short, often one-dimensional answers while the concept maps tends to give richer answers with more content and several dimensions of the concept. Students are vague and not enough specific when they try to explain verbally how they understand a concept.

The concept maps seem to reveal some properties of the concept development that are of interest. What are the advantages of using concept maps as answer form for students? From the example it is clear that the maps give the student better opportunities to express her concept image. It obviously invites to more multidimensional answers than a sentence which in its form is linear. The written answer does not open for hierarchy or additional lines of thought in the same way as the map. Knowledge that students express through a concept map seems to be lasting.

The way I used maps to make an a priori analysis of intended mathematical learning and then use another map to express students' answers in propositions and compare them has not been found in other mathematics education research reports (at least not in accessible journals). On the other hand, to study concept development over time maps have been used by several researchers. McGowen and Tall (1999) traced students cognitive development throughout a mathematics course by the use of concept maps at intervals during the course. They drew schematic diagrams of the maps of each student in order to see how students build maps by keeping some old elements, reorganising and introducing new elements. The results show that high achieving students "can show a level of flexible thinking building rich collages on anchoring concepts that develop in sophistication and power. The low achievers however reveal few stable concepts with cognitive collages that have few stable elements and leave the student with increasingly desperate efforts to use learned routines in inflexible and often inappropriate ways" (p. 287). Their findings are consistent with what I have shown. Thus it is obvious that concept maps can be used as a tool in research and in different ways as has been described here.

7 Concluding remarks

Obviously the problems that drive the research on student teachers' conceptual development derive from my experience as a mathematics teacher educator and originate from a desire to better understand the process during teacher education and to improve teacher education in mathematics. Can this be achieved if we know more about concept development? Can students experience more meaningful learning if we use new knowledge on concept development? Novak (1993) writes: "What remains to be demonstrated are the positive results that will occur in schools or other educational settings when the best that we know about human constructivism is applied widely. To my knowledge no school comes close to wide-scale use of such practices, even though there are no financial or human constraints that preclude this."

Can mathematics teacher educators design better learning situations for students when they know more about the cognitive development of students? Improvement of our knowledge on student teachers' development of concepts during the education might contribute in a constructive way to the redesign of teacher education. One outcome from the study related here was that the learning of the teacher educators resulted in a project for development of the professional language of a mathematics teacher, which was influential for both the students and the teacher educators (Grevholm, 2003b; Grevholm & Holmberg, 2004, Grevholm, 2004). Another outcome is a model of mathematics teacher education in the form of a concept map showing the development of a professional identity for the teacher (Grevholm, 2006, 2007).

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CONCEPT MAPS FOR COMBINING HARD AND SOFT SYSTEM THINKING IN THE MANAGEMENT OF SOCIO-ECOSYSTEMS

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Abstract. Despite the huge increase in the number of quantitative modeller studies undertaken, little attention in the literature has been given to the communication process among modellers, the researchers and local stakeholders. However, such communication is necessary to ensure that this research effort becomes a useful tool in the decision-making process. The work described here is based on the systems paradigm, and combines scientific environmental analysis and ecosystem modeller (the *hard-system* approach*)* with *soft-system* participatory processes. The development of concept maps is the main tool of the methodology proposed here: combining soft and hard approaches, concept maps are first developed with the involvement of local people and local experts and then used to guide the design of quantitative models. This paper discusses how concept maps and quantitative models were developed to capture the complexity of social and ecological systems in a declarative, systems-oriented and user-friendly manner, assisting stakeholders to increase the knowledge of problems and make decisions. Finally, advantages and disadvantages of the proposed methodology are discussed.

1 Introduction

What is the best way of producing good decision support tools for the management of mountain areas in developing countries, that take full account of local people's needs, aspirations and knowledge?

Currently major gaps exist in the knowledge of crucial socio-ecosystem dynamics of the mountain complexes, and no clear mechanism is established linking research with management priorities. Typically, resource management projects employ methodologies based on environmental analysis and ecosystem modeller *(hard-system),* or on participatory processes *(soft-system)*. Each approach has its own strengths in dealing with the complexity of systems from a variety of perspectives. However, a major existing gap is the lack of a clear methodology for integrating these two approaches.

We start by introducing the soft and hard tools that can be used for the management of socio-ecosystems in mountain areas. We then show how they can be linked together in order to ensure a smooth flow of information between the conceptualisation phase of the system and its quantitative analysis, and between the people's needs and the development of solutions.

1.1 Soft Systems Methodology

The participatory process and qualitative research were chosen here as suitable Soft Systems Methodologies for working in socio-ecosystem (SES) management.

1.1.1 The participatory process

Key stakeholders are involved in the iterative process of system conceptualisation, development and implementation to assure that real user needs are answered and a sustainable process of improved natural resource management is established. We suggest the use of three kinds of tools:

a) *Workshops* to develop a common management process for researchers, stakeholders and modellers.
b) *Scenario planning* exercise*s* to explore possible long-term scenarios for these ecosystems. Scenario planning is a technique means to identify and stimulate analysis around alternative futures as a way of short-circuiting biased and entrenched views of the world and prepare for developments which could not be anticipated by simply extrapolating past trends.
c) C*apacity building* of resource people involved in the management and study of SES is here considered an essential element in a participatory process that uses scientific and technological resources and tools. In fact Soft Systems Methodology requires that participants adapt to the overall approach. Through formal

and informal training a higher awareness of the aims and the proposed methodologies is required for all actors involved in the process.

1.1.2 Qualitative research

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 and Guba, 1985). The researcher builds a complex, holistic picture, analyses words, reports detailed views of informants and conducts the study in a natural setting. Concept maps can provide one strategy to deal with the methodological challenges of qualitative research. A concept map (Novak, 1998) can be used to frame a research project, summarise qualitative data, analyse themes and interconnections in a study, and present findings. The maps allow the researcher to see participants' meaning as well as, the connections that participants discuss across concepts or bodies of knowledge (Daley B. J., 2004).

Sophisticated computerised software programs have been developed to assist with the data analysis process in qualitative research. In our project we decided to use CmapTools®, mainly because it is a client-server software environment that greatly facilitates the construction and sharing of concept maps. 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, and Pérez, 2003). CmapTools® supports the construction of "knowledge models": sets of concept maps and associated resources about a particular topic (Cañas, Hill, and Lott, 2003) (Novak and Cañas, 2004).

1.2 Hard Systems Methodology

1.2.1 Quantitative research

The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to natural phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships. We use System Dynamics (SD) because it is the modeller approach that most closely matches the requirements of the Systems Paradigm. It uses computer simulations to study systems behavior and impact of alternative policies. The SD modeller software we decided to use is called Simile, and has been designed by Simulistics Ltd. (UK) (http://www.simulistics.com) for creating quantitative computer models.

Simile uses a declarative modeller approach to represent the interactions in complex systems in a clearly structured, visually intuitive way. Simile is billed as a "visual modeller environment", meaning that models are developed diagrammatically (as opposed to writing lines of text, as in a programming language or a simulation language). There are significant advantages in adopting a declarative modelling approach (Muetzelfeldt, 2004).

First, there is no risk of the description of the model failing to match the implementation of the model: the description *is* the implementation. Second, once a model is represented declaratively, one can do many things with it as well as just simulating its behavior: for example, generate descriptions in a variety of formats, interrogate its structure, compare its structure with that of another model, or transform it into a simpler or more complex model. Finally, the adoption of a declarative modelling approach encourages the development of common standards for representing models, the distributed development of modelling tools, and the sustainability of the effort put into developing models.

As mentioned above, this paper is concerned with the need to integrate soft and hard systems approaches. Therefore, the key innovation proposed here is the development of a methodology to support socio-ecosystem decision-makers focused on reducing the gap between research and management priorities. The use of concept maps is a key element of this strategy. On the one hand, it helps in managing the information flow in the participatory process, while on the other hand it helps to create a link between qualitative and quantitative modelling.

2 The case-study

The HKKH Partnership Project aims to improve ecosystem management in the Hindu Kush-Karakoram-Himalaya region (www.hkkhpartnership.org). It was developed in the framework of the priorities defined in the World Summit on Sustainable Development (WSSD) 2002 draft plan of implementation and considering the recommendations made for achieving successful implementation of the priorities identified in the Agenda 21. It is funded by the Government of Italy (DGCS). It is a partnership initiative and the executing agencies (partners) are:

- the International Centre for Integrated Mountain Development (ICIMOD) (www.icimod.org);
- Ev-K2-CNR (www.evk2cnr.org);
- CESVI-Cooperazione e Sviluppo (www.cesvi.org);
- IUCN Country Offices in China, Nepal and Pakistan (www.iucn.org).

The activities are focused in three national parks: Sagarmatha National Park (SNP) in Nepal, Central Karakoram National Park (CKNP) in Pakistan and Quomolongma Nature Preserve (QNP) in Tibet Autonomous Region of PR China. The implementation of the project recognises the specific characteristics of each site, and allows for political and knowledge constraints. This paper focuses on the SNP site in Nepal, because there is more knowledge about the socio-ecological dynamics of this site, and the park management is well developed.

3 Methods

The methodological approach described in this paper is inspired by the approach to the management of SESs proposed by Walker et al.(2002), and summarised below. The authors argue for an approach which recognises that uncertainty is an inherent characteristic of many systems: we need to live within the system, rather than setting goals based on unattainable assumptions. In this perspective, ecosystem management hinges on strengthening the resilience of the system in case we wish to maintain it in its present configuration; or to undermine the system resilience if we wish to move the system configuration to a different state.

Walker's framework is based on four steps:

1. System description through stakeholder participation;
2. Identification of possible future trajectories of the system;
3. Quantitative analysis of system;
4. Participatory and integrated assessment of policy and management implications.

3.1 System description through stakeholder participation

In this step, we create qualitative models of the system based on the identification or definition of spatial boundaries ecosystem services, processes and change - the institutional and legal factors and power relations which influence patterns of decisions by stakeholders. The key tool for this qualitative process is the concept map. This allows us on the one hand to manage the information flow in the participatory process, while on the other hand to create a link between qualitative and quantitative modelling.

To begin with, no specific rules were laid down for stakeholders to build concept maps. In this way the concept maps were able to to trigger lateral thinking and elucidate the real management problems. However, we found that this approach made subsequent use of the concept maps more difficult, since the qualitative analysis had to be translated first into a qualitative model and then used by modellers for quantitative translation.

Therefore, we decided to restrict the notation to be used in the concept maps, in order to ensure that they would be of greater use for the subsequent qualitative and quantitative modelling. The main actors involved in the standardisation and in the construction of qualitative models were the domain researchers in relation to their relevant expertise and project experts in the modelling exercise. Specific training activities on using concept maps and CmapTools® were organised and a Protocol for the preparation of the qualitative diagrams in CmapTools® was prepared.

3.1.1 The Protocol for the qualitative modelling

This Protocol provides guidance on the diagrammatic notation to be used in the Cmaps, and the section headings and content to be used in the associated documentation. The aim of the Protocol is to introduce some degree of formality into the qualitative modelling process.

The Protocol includes general rules such as:

- The concept maps should show the flow of information from the inputs to the management outcomes. However, it is essential that feedback interactions are also captured and highlighted.
- This phase does not imply the identification of data required by the model. However, the domain researchers should be starting to consider the quantitative variables which could correspond to the concepts expressed in the concept map.
- The files are ordered alpha-numerically on the CmapServers. In order to have the files ordered by version/date, it is useful to have a versioning or dating system which gets successive versions of the model listed sequentially. The proposed system is:
  [model name] [yy] [mm] [dd] [version] [author initials]
- Every concept map project is composed of:
  - the concept map itself, realised in the CmapTools ® with relevant annotations;
  - a folder in CmapServers with descriptions defining key concepts;
  - a document describing the concept map;

The Protocol includes guidance on the Cmap diagramming, including a table specifying the colour to be used for the nodes, according to the concept they represent.

Colour of the concept	Meaning
Blue	Policy levers
Green	Indicators of performance
Pink	Intermediate variables
Yellow	Input data
Orange	Connection to other sub-models
Red	Economical aspects regarding the policy
Purple	Connection with the sub-model documentation

In addition, the protocol includes guidance on the labels to be used on the connectors (i.e. the arrows/arcs) used to link nodes together.

Relationship type	Linking phrases	Comments
Causal	+, -, +/-	Used to describe positive, negative relationships or when they can be either positive and negative depending on specific conditions.
Spatial	through, near, within, is-next-to, from, to	Used to describe spatial relationships. Example: tourists *go though* valleys. The linking phrases can be associated with the appropriate verb.
Time	before, after, during, delays	Used to describe temporal relationships. Example: snow leopard *migrates during* winter. The linking phrases can be associated with the appropriate verb.
Action	creates, destroys	Used to describe relationships of population dynamics. Example: snow leopard *predates* musk deer. In this case *predates* is used as a synonym of *destroys.* Synonyms of cretes and destroys can be used as appropriate.
Undefined	influence	Used to describe relationships that are known but cannot be described according to the linking phrases available. This is a generic type of relationship and should be used only when all the other options available have been checked and discarded.
Unknown	?	Used to describe relationship of unknown nature. The narrative description must be provided in a file attached to the connector. The use "unknown" relationship should be as limited as possible.

The Protocol also includes guidelines on the preparation of associated documentation, as a Word document. The aim of this is to ensure a uniform approach across the various models, and to ensure that important information is included. It specifies that the documentation should have the following sections:

- Aims: the aim of the submodel
- Narrative description: Description in words of the Cmap diagram
- Time step: the time step over which the system changes
- Spatial disaggregation: how space should be represented
- Management levers: the variables available for a manager to change, to influence the system towards desired outcomes.
- Assumptions
- Links to other submodels: information coming from or going to other submodels
- Variable requirements: expressing a (mathematical) variable that can be used for a particular concept
- Open problems about the research activity

In Figure 1 an example of a concept map developing following the guidelines is shown.

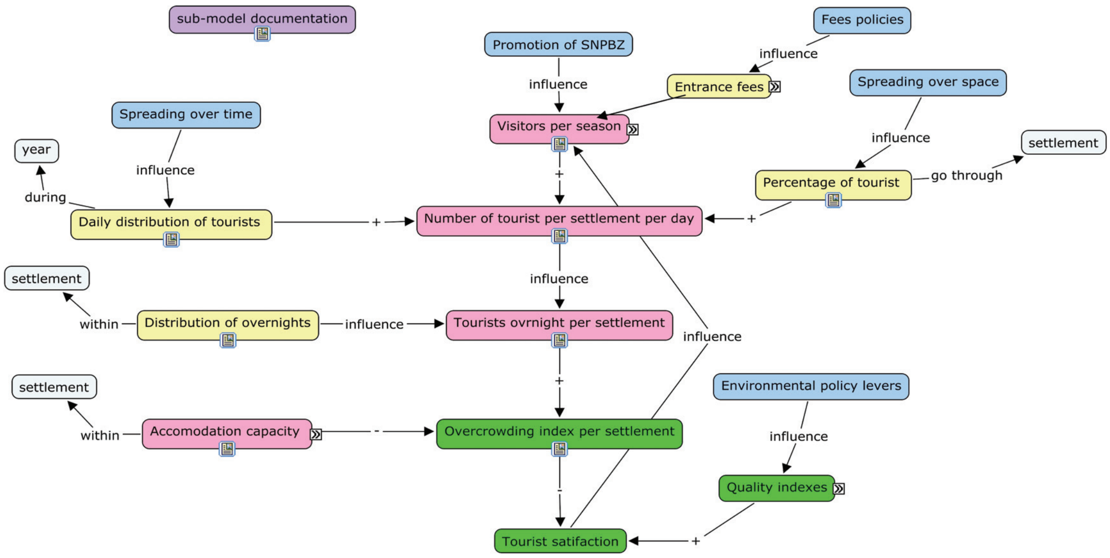

Figure 1. Concept map of the qualitative model for the analysis of solid waste management in SNP

3.2 *Identification of past and possible future trajectories of the system*

A scenario planning exercise was organised, at the same time as the creation of the qualitative models presented above, with the participation of 15 people from the SNP site, along with staff and experts of each partner (Daconto, 2007; Daconto and Lhakpa Sherpa, 2007). Participants were asked to identify through cards the key events and changes in SNP over the last 100 years and to land in the park in 25 years. The outcomes of this experimental exercise was the formulation of a *text-based representation* for past and alternative future system configurations, linking the past and present state and events with future hypothetical states and events. The facilitators assisted the groups and, after the meeting, reviewed the initial storylines to achieve a minimum of uniformity in style, eliminate gross inconsistencies and strengthen coherence.

Subsequently project resources translated the storylines in the concept maps to bring out the main changes (impacts) that have occurred in the SNP, the key elements (drivers) that drove and will drive the change, and the future expectations (scenarios). Figure 2 shows a concise representation of a concept map translated from narrative outputs of the scenario planning. On the left it is possible to observe that stakeholders identified the increase in tourism, the increase in immigration, and the increase in temperature as the main drivers that have caused impacts on environmental quality and on the quality of life. On the right it is possible to observe four alternative future scenarios based on the assumption of a further increase in tourism and on the new possible trajectories due to the recent Nepali revolution. The four scenarios are based on the four possible combinations of two alternative levels of centralisation of SNP governance and on two alternative roles of outside investors that could play a part in the management of new local infrastructure needs due to the assumed increase in the number of tourists.

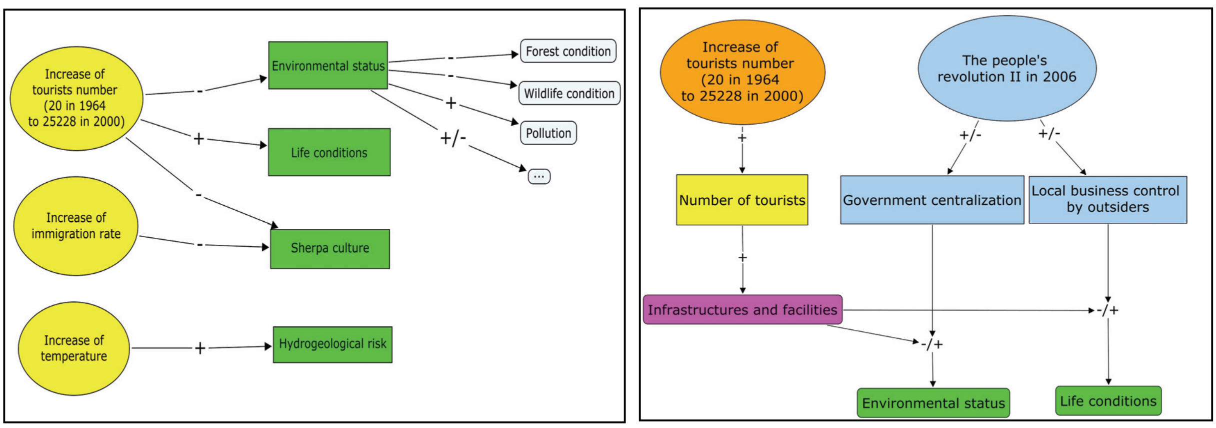

Figure 2. Left: Key events and changes in SNP over the last 100 years; Right: Alternative future scenarios in 25 years in SNP

This translation of the narrative output of the scenario planning into concept maps is necessary to ensure that the qualitative and quantitative modelling is focussed on a long term (strategic) timeframe, as a first priority. How to proceed for the full integration of these concepts into the modelling process will be considered in the discussion section.

3.3 *Quantitative analysis of the system*

In this step the *System description* performed through concept maps (step 1) is analysed to identify controlling variables at different scales, their rates, the non-linear behaviour of variables, and threshold effects. As described above, Systems Dynamics, based on the methodology of Sterman (2001), Binder et. al. (2005), was used as a hard system method to define the functioning of key process in socio-ecosystem function.The Simile modelling environment (Muetzelfeldt and Massheder, 2003) was used to implement the resulting models.

For the quantitative modelling process we use the following steps. It should be noted that the process includes iterative testing and refinement to ensure the validity, accuracy and operation of the models.

1. Quantitative red models: qualitative diagrams are translated in Simile model structure. Only the model structure is developed (the models in this phase are developed without data). These empty models are called here red models. In this phase stocks and flows, the main feedback loops, in the system are identified.
2. Model data requirement: the analysis of the structure will identify the knowledge and data required to define relationships (equations) and baseline values of model variables.
3. Data gap analysis: data gaps are identified by screening existing sources with reference to the model structure data requirements and if necessary research is conducted to complement data.
4. Metadata for data: available data are retrieved, classified and stored according to the model requirements;
5. Quantitative black models: production of models based on guessed data and relationship.
6. Simulations: the results are analysed.
7. The models and results are sent to stakeholders for review and feedbacks.

In Figure 3 the main quantitative modelling steps are described, while Figure 4 shows an an example of the quantitative model developed in Simile. The example is the same used for the qualitative modeller (Fig. 1).

Work to date has concentrated on producing the 'red' System Dynamics models in Simile - i.e. the models without numeric values and equations (step 1 in the above list). Work is underway to obtain the necessary data and to establish the appropriate equations to use in the model (step 2-5). Once this has been achieved, the simulations will be run and the results analysed (steps 6,7).

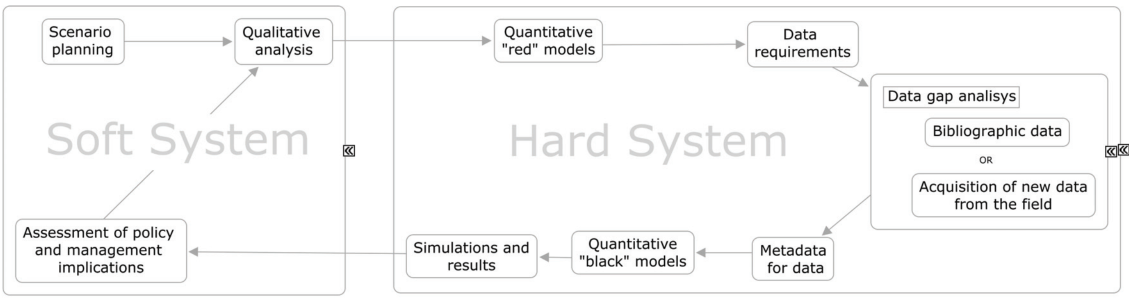

Figure 3. Steps proposed in the HKKH Partnership Project for the overall socio-ecosystem analysis and modelling

3.4 *Assessment of policy and management implications*

This is the final stage of the process, and is essential for a successful participatory and integrated approach. The stakeholders will evaluate the implications of a different set of policies on the resilience mechanisms identified in step 3. Hence policy options are identified, which can guide management towards the desired system goals.

4 Discussion

In this section we need discuss the lesson learn in the application of concept maps for combining hard and soft system thinking in the management of socio-ecosystems. For each of the four steps of the Walker's framework for the management of SESs applied in this work, we asked relevant project experts to point out advantages and disadvantages in the use of concept maps and CmapTools® in this context.

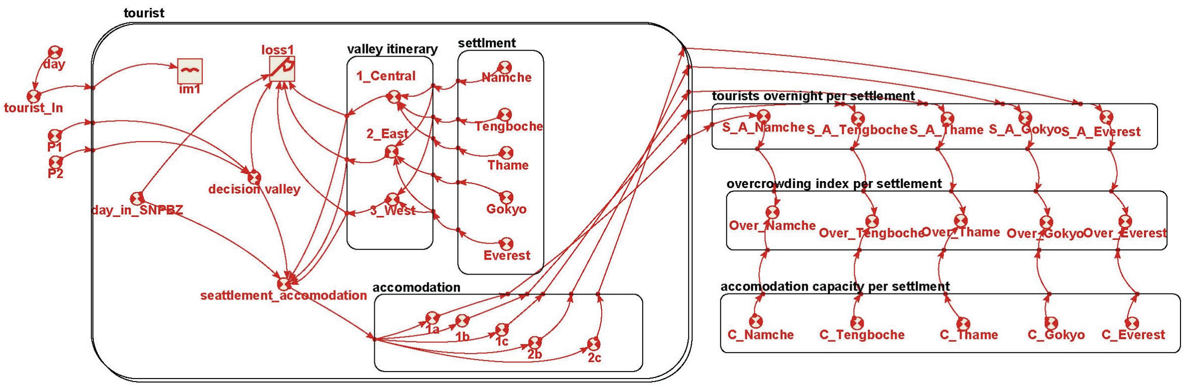

Figure 4. Example of declarative quantitative model developed in Simile: the tourism sub-model.

4.1 System description through stakeholder participation

The key drivers (pressures) identified by the groups, as well as the impacts on SESs, were used to develop the topics and themes (sub-models) for the decision-making modelling.

a) Because CmapTools has no mechanism for specifying that nodes or arcs can be assigned to a particular category, we developed a protocol to specify an indirect mechanism for classifying concepts through encouraging the use of colours for nodes, and labels for arcs. The proposed guidance seems to have an appropriate level of abstraction. It certainly helps in the later stages of the modelling process to have qualitative diagrams which have been constructed according to these guidelines, since these terms correspond in part to those used in the actual mathematical models. On the other hand, the conventions proposed here are not as technical as those used in formal mathematical modelling, so will be easier for the local experts to work with.
b) The protocol recognises that in some cases the people preparing the qualitative diagram may have information on the mathematical form of the relationship used to compute a particular variable. However, in practice the use of formal mathematical expressions seem inappropriate at this stage of the modelling process.
c) With CmapServers it is possible create a folder on the internet facilitating the sharing of concept maps. However, we note that CmapServers should improve their capability to create discussion space during the concept map construction process. Annotations facilities provided by CmapTools are not enough to support and encourage such interaction. An alternative solution is to use a *WIKI* in which one can add conceptual maps and relevant documentation, user-editable pages, and discussion forums, as well as well as customisable index pages for accessing the concept maps and related content.

4.2 Identification of possible future trajectories of the system

a) The methodology should be further adapted and simplified when stakeholders are not fluent in English. One idea is to use participatory drama to engage participants through an effective role-playing exercise.
b) Storylines developed during scenario planning required elaboration by technical people to enrich the analysis and translate the narrative into concept maps. This is one way of making a link between the soft system approach and the modelling process. The main drivers and impacts to develop modelling scenarios have been identified and already considered in the modelling process. The future scenarios suggest that in general local park management is sufficient for ensuring a reduced impact on the environment. This helps in reducing the amount of work, since we need consider only local policy levers rather than those associated with central government.

4.3 Quantitative analysis of system

As discussed above, our concept maps may be either unstructured or structured. The first has the advantage of identifying ideas, of investigating unstructured problems, looking at the problem situation from different perspectives without restrictions. This approach is suitable for the start of the process, working with a large number of participants who do not have a strong background in analytical research. However, if the final aim of the analysis is to develop quantitative models, a system of rules for constructing the concept maps is needed. In this case, the concept maps can be considered to be real qualitative models. The guidelines are more likely to be followed if training is provided for the concept map-makers. The degree of standardisation of a map can be considered adequate when possible misunderstandings in map interpretation are avoided, and for this reason the Cmaps must be properly documented. We conclude this section by pointing out the dynamic nature of concept maps. To speak about the “final version” of a concept map, developed by a large number of map-makers and users in an iterative process, is meaningless. Several versions of the same concept map can live together to reflect different conceptualisations by the map developers, and different uses for the map. The first versions of Cmaps should be developed directly by local people and they will show the interactions in the systems they are familiar with; while the latter ones will have a major orientation towards quantitative modelling, and their development should be supported by experienced modellers. The main thing is to maintain a close logical connection between each stage of the concept map process, and to document any non-obvious deviations from a straightforward conversion between one diagram and the next.

4.4 Assessment of policy and management implications

Once the quantitative modelling has been finished, a new participatory process should start. A strong effort must be made to ensure effective communication between modellers, researchers and local stakeholders. This is necessary to ensure that these research results become a useful tool in the decision-making process. It also helps if concept maps are used to show alternative management scenarios.

5 Summary

Concept maps offer a powerful way for integrating hard and soft system methodologies, and make it possible to create innovative models for socio-ecosystem management. Furthermore, concept maps afford opportunities to integrate the concept of management-oriented research into the methodology, bridging between researchers and decision-makers. From the identification of problems and ideas, passing through a structured qualitative analysis, to the sharing of alternative management modelling scenarios, all actors involved in socio-ecosystem management using concept maps can play an active role in the process. Short and long term manager perspective can be brought into the modelling process, making it more likely that the results will be incorporated into management decisions. This paper points out that different levels of concept map structure are required, depending on the intended use and the ability of the concept map makers and the users.. Training courses to increase the capacity to build concept maps and to use the relevant software are strongly recommended in order to improve the map quality. We conclude by underlining the value of CmapTools® in following the concept maps developing and suggesting and improving of tools to facilitate the communication among map makers and users.

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CONCEPT MAPS IN PANAMANIAN CLASSROOMS: SEARCHING FOR PHOTOGRAPHS OF KNOWLEDGE

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Abstract: Concept Maps (Cmaps) were first conceived as a tool to represent and organize knowledge (Novak, 1984). Currently, this premise has been expanded due to the versatility of this tool, because Cmaps also provide for the construction of new knowledge at the individual level and in collaboration processes. It could be thought that Cmaps allow us to manage knowledge. Achieving that a Cmap reflects the knowledge of its builder is a task that requires time and dedication. This paper emphasizes strategies that, according to the experience gained in the classroom, could speed up the process of learning how to use the tool. By having greater skill in the use of the tool, it could be much easier to portrait the individual or collective knowledge in a Cmap. This paper presents the experience carried out in Panamá with three classrooms of 4TH graders in José María Torrijos elementary school; they were aided by their teachers and a group of facilitators from Conéctate al Conocimiento. The learners' training was carried out taking into consideration the necessity of using concept maps to "photograph" the different phases of a learning process, specifically for a Scientific Inquiry Project. The "photographs" of the process, as well as the results from the application of Cmaps are showcased in this paper. All this effort takes place in the search for the unification of two important proposals regarding educational matters in Panamá: Concept Maps and Scientific Inquiry Projects at the elementary school level. In Panamá, the concept map tool is being implemented massively in elementary schools through Conéctate al Conocimiento project, which is an initiative put forward by the Presidency Secretariat for Government Innovation (Tarté, 2006). At the same time, a science inquiry project named "Hagamos Ciencias" is being implemented, which belongs to the educational project area of another government entity, the National Secretariat for Science, Technology and Innovation. The present effort is concentrated in polishing the model and its application, as well as the way in which results are generated and processed. It is hoped that this model will be applicable and useful to others.

1 Introduction

Basically, every activity could imply some degree of learning. Although if what are intended to be achieved are pedagogical objectives, it is necessary to implement measures (pedagogical strategies) in order to achieve these objectives. For teachers to achieve this, it is necessary to resort to means that provide for the learner to "learn" that which is set as an objective. Currently Cmaps have become a good instance of a mean to learn. Since they were conceived by J. Novak in the early 70's, they have been present in every educational task. In Panama, Cmaps are implemented in elementary schools through the Conéctate al Conocimiento project (Tarté 2006). In the approach presented by the project, the issue of dexterity in constructing Cmaps is relevant. Beside this, some technological tools are also being implemented, such as the CmapTools software (Cañas, et al., 2004) and such tools are enhanced with Internet access in the schools. All this effort is towards the promotion on knowledge construction and collaboration in such construction. The aforementioned requires constant practice and feedback if what one pretends to achieve is that the tool becomes part of the individual, that means, that the individual can express through it without being limited by the tool, but quite the contrary, that the tool becomes a springboard to build, express and share his/her knowledge. This paper will show some ideas on how could dexterity in the construction of Cmaps be achieved. It is not a recipe book that can be applied in any context, but a concrete experience that allows us to guide and point out some key issues in school activities regarding the use of Cmaps. What is wished to point out is the objective of this paper: to use Cmaps as a tool to compare the knowledge previous to an inquiry experience versus what was learned after the inquiry experience was carried out. In this way, the Cmap is a useful tool for learners to represent and enrich their knowledge as well as to achieve the objective of this research by becoming portraits of knowledge.

1.1 Using Concept Maps to photograph Knowledge

Using a tool implies knowing how and for what it is used. Cmaps are not above this fact. It can't be expected that Cmaps reflect the knowledge of the person building it, if he or she doesn't know how to use the tool. The aforementioned seems obvious, however, the approaches on "how" one gets to have dexterity in the construction of Cmaps are diverse. Cmaps could be used to know, in an approximated fashion, what an individual knows. The aforesaid is true if and only if the person has dexterity constructing Cmaps. We will call "Faithful Cmaps"[1] those concept maps that are the closest approximation to what a person has in his or her mind

[1] *When saying "faithful" it refers to the closest approximation that can be achieved between the Cmap and the knowledge of a person. Although what was just said presents an issue about the measurement of the approximation, it will suffice for now with the fact that Cmaps are a means of expression for an individual and we are interested in finding out if the person is expressing his/her ideas in an understandable fashion in the Cmap, and that is not the same as the individual expressing "all" his/her knowledge about a topic.*

in regards to a topic. Faithful Cmaps would be those that reflect the knowledge of an individual free from the bias introduced by the use of the tool. A comparison could be made, in order to understand this idea, with written language; we are able to express ideas in written, only when we are proficient in it and consequently the "ideas that are thought" are equivalent to the "ideas that are written". Besides all these, Cmaps are a form of language and a means for dialogue at the same time. A dialogue that can be interpersonal (several individuals) and "intrapersonal" (inner dialogue, individual meta-cognition). That's why Cmaps can be seen as a "camera" that allows us to capture, in an increasing or decreasing degree, the knowledge that an individual has and how he/she has organized it. Obviously the quality of the photograph depends on the quality of the camera and the ability of the photographer. As a first step to approach the achievement of faithful Cmaps it has been proposed that the Cmaps keep a "propositional structure." This refers to place special emphasis in well defined concepts and that the relations (linking phrases) between concepts express clear ideas (Fig. 1) so as to have a "unit with meaning" or proposition; within this propositional structure, it is recommended the predominance of binary propositions (Miller, 2008), and not long lineal structures that are nothing more that the transcription of a sentence into a Cmap format.

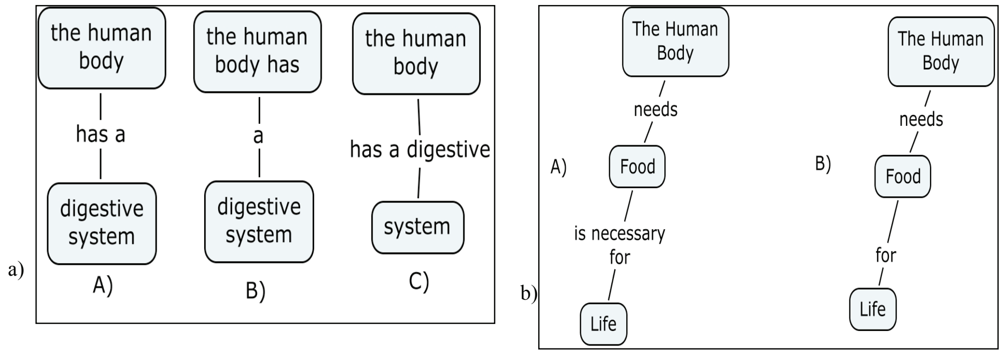

Figure 1. a) Three proposition A, B y C that when read express the same idea, however the disposition of the elements let us see that in A the idea is clear (concepts are easily recognizable and linking phrases are clear), on B the concept "the human body" is together with the verb "has", which shows that it is not completely clear how the concept is defined. In the case of C it could be seen that the concept "digestive system" has been segmented leaving "system" as the concept, in this case the concept is not accurate because it lacks its adjective "digestive" which appears in the link. It is important to point out that it is not only a matter of wrong spatial distribution of elements within the boxes corresponding to links and concepts, it is clear that the propositional notion has not being assimilated in cases B and C. b) Two sets of propositions, in case A it can be seen how starting from a concept (the human body, for instance) it arrives to another concept (food), when starting a new proposition from the arriving concept, this one becomes in the starting concept (food-----is necessary for-----life) and that process is repeated every time a new proposition is generating from a given concept. On the other hand, on B it is clear that if you read on "the human body needs food for life" it makes sense, however the isolated propositions are not clearly understood as in the case of A, all this mean is that in B case it is necessary to improve the skill in the construction of proposition. Notwithstanding that they try to express the same idea, on both cases, the set A has been elaborated propositionally, which is not the case of B.

2 Methodology

2.1 Searching for "Faithful Cmaps" to compare learning

The necessity of this research to make use of Cmaps to "photograph" different phases of a learning process comes into being within the framework of establishing a qualitative comparison of the Cmaps built by learners before and after they carry out the activities related to the "*Electrical Circuit*" Science Inquiry Project, which is part of the projects from Hagamos Ciencia.[2]. As an attempt to get closer to obtain faithful Cmaps the following actions were proposed: a) prior training for teachers and learners in the construction of Cmaps, b) "Translation mediation" on the part of facilitators during the Cmaps construction process by the learners (this term will be explained further on), and c) interviews to the learners after the construction on the Cmaps which were build before and after the Hagamos Ciencia experiments. Although we have focused on the learning process in an inquiry project, we consider that the following process could be applied in other scenarios; it may also be applied when some other kind of learning takes place.

a) Prior training for teachers and learners in the construction of Cmaps

[2] Hagamos Ciencia, directed by Dr. María Heller, is part of the projects carried out by the Secretariat of Science, Technology and Innovation of Panamá (for further information www.senacyt.gob.pa)

The teachers' training took place before the learners' training, and it was carried out in a personalized manner (one to one facilitator-teacher). The learners' training was carried out in a collective manner with each classroom. Both training encompassed two phases: first, introduction to the tool and later reinforcement.
The introduction, for teachers as well as for learners, consisted in a session in which the basic notions for the construction of Cmaps were presented. This involved the construction of a Cmap. Each teacher constructed an individual Cmap. The learners' groups constructed each a collective Cmap in the board.[3] On both cases, emphasis was made in the propositional structure. The teachers were offered, additionally, strategies to help learners in the construction of Cmaps with good propositional structure. Some of the Cmaps built during this phase are shown on Fig. 2, on figure 2a is one Cmap made by one of the teachers and the on figure 2b is one Cmap made by the a group of learners.

The reinforcement consisted in the construction of Cmaps about the topics dealt with during classes. During this phase the teacher could reinforce his/her ability as a facilitator and the learners reinforced their abilities in the construction of Cmaps. This phase had an approximately duration of month and a half. All the Cmaps built from hence on were constructed in groups of 4 to 5 learners.

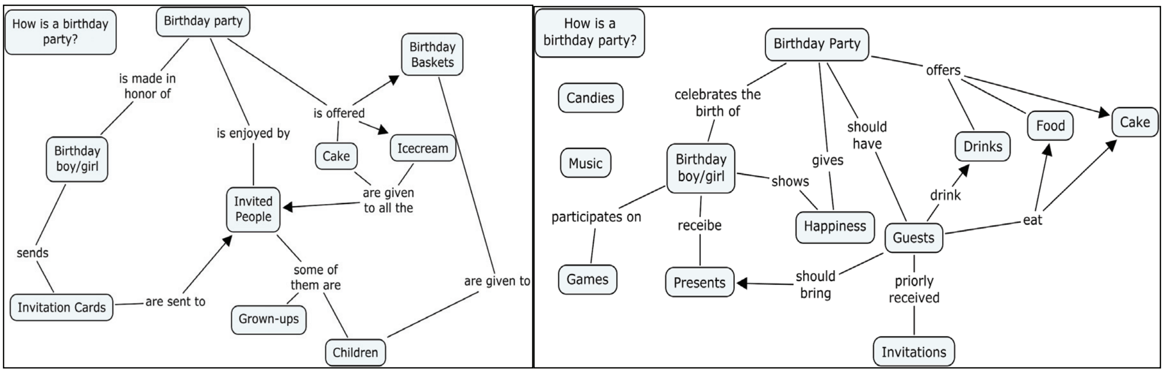

Figure 2. a) Concept map built by one of the 4th grade teachers of José María Torrijos elementary school, b) Concept Map built by a group of learners from 4th grade of José María Torrijos elementary school. (Transcribed from the board using CmapTools by one of the facilitators from Conéctate al Conocimiento)

b) "Translation mediation" during the Cmaps construction process

During the construction of all the Cmaps in this study, the facilitators of Conéctate al Conocimiento and the teachers from the school mediated in the process. The desire that the Cmaps reflect the ideas of the learners led the role of the mediator to consist on assuring that the propositional structure would be fulfilled in most of the cases. As it is shown further on in this article, this is of vital importance in order to interpret and compare the pre and post inquiry activity Cmaps. This is why it was intended that, if the learners could not structure the propositions correctly, the facilitators and the teachers would help them in this regard.

The abovementioned was carried out only with the structure of the idea, not in what it has to do with de validity of the idea; nor the undertone of the idea was judged. The team of learners gave their ideas; if it was necessary they were helped in structuring them as propositions without changing their original sense. This process was named translation mediation, because it is, literarily speaking, translating what is expressed naturally to a propositional structure. It was decided to follow this approach in order to enhance the Cmaps approximation to the learners' knowledge, all this with the objective of observing and comparing the previous knowledge versus the knowledge gained after the inquiry project activities. This approach was followed for the Cmaps constructed during the reinforcement as well as for the Cmaps constructed for comparison purposes. As an example illustrating this please refer to Fig. 3.

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[3] To have the teachers starting the construction of their first training Cmap, the focus question was "How is a birthday party?" This question was chosen because, according to the experience gained during the Conéctate al Conocimiento workshops, it is the kind of focus question that lowers the topic profile (besides being fun) and it allows for the person to focus on the Cmap and not on the topic. Usually a complicated topic carries with itself "additional noise" at the moment of constructing Cmaps, although it is still needed to systematize the Conéctate al Conocimiento workshop experiences in order to give a more responsible statement in this regard.

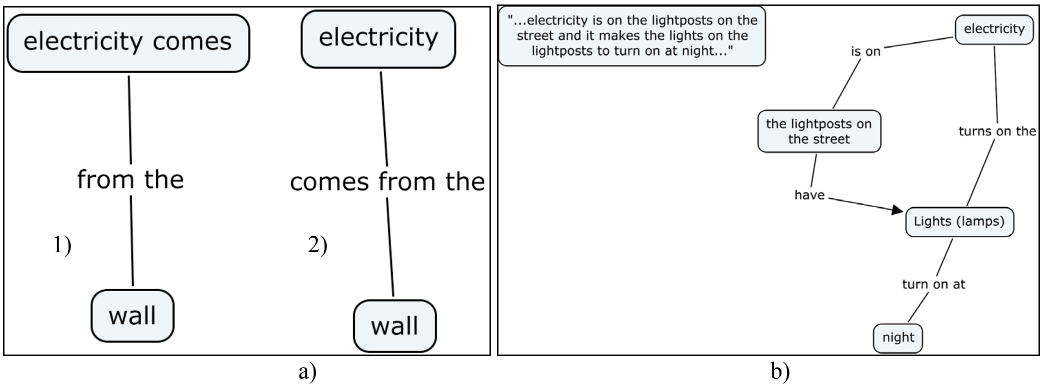


Figure 3. a) Example of propositions meditated by the facilitator, in this case it is not discussed with the learner the validity of the statement "electricity comes from the wall", the intervention was limited only to help structure the propositions correctly. In a-1 the first concept is "electricity" only while "comes from the" is the linking phrase and "wall" is the last concept. The facilitator helped only in improving the structure (a-2). b) The textual words expressed by the learners could be read on the upper right square. After mediating with the learners it could be translated to propositional structures.

c) Interviews to the learners after the construction of the Cmaps

The interviews were not made during the reinforcement sessions, they were only made after the construction of the pre and post experience Cmaps for Electrical Circuit and they were made with the purpose of collecting the learners ideas with a higher degree of detail. The interview process consisted on asking the group of learners to explain, in their own words, the ideas that were on their Cmaps. They were asked enhancement and inquiry questions, but not verification questions (Chacón, 2006) in order not to interfere with their previous knowledge, most of all in the case of the Cmaps previous to the experiences. It is important to point out how trained one must be in order to perform the interviews, above all for the ones directed to children between 9 and 10 years of age. The limitations presented when performing the interviews were due to the lack of this ability, because rehearsing helps improve the model and for a later application[4] the interview process could be refined so more details that do not appear on the Cmaps could be extracted from the learners.

2.2 Model Application: Photograph of before and after the Electrical Circuit experiences

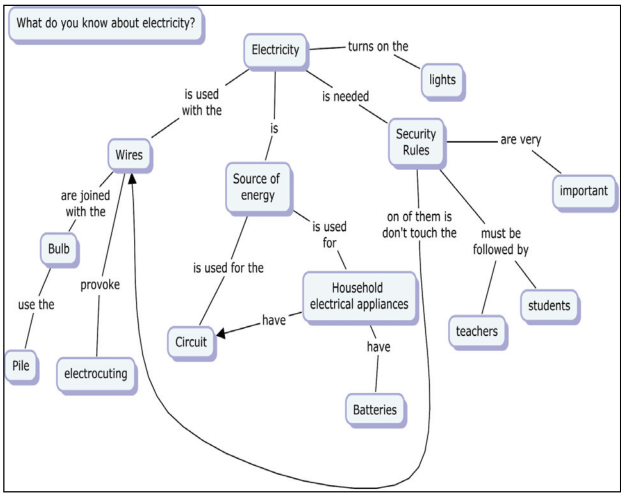
The process was carried out in three fourth grade classrooms from the José María Torrijos elementary school; 4th grade A (with 25 learners), 4th grade B (with 29 learners) and 4th grade C (with 27 learners). These classrooms are attended by teachers Julio Vergara, Omaida Torres and Eirené Bravo respectively. Each classroom was divided in teams of 5 or 6 learners that totalled 15 teams (an average of five teams per classroom). Every team built a first Cmap previous to the experiment (Cmap_{pre}). The focus question for the Cmap_{pre} was: What do you know about electricity? The learners were given a list of base-line concepts, that is, a "parking lot of concepts"[5] (PLOC) [6]. All of the concepts given to them formed part of the lesson to come on Electrical Circuits project. The time allowed for the construction was about an hour and a half for each team. All the necessary steps were taken in order to isolate as much as possible the teams from each other within a given classroom, although the physical size of the classrooms in function to the number of students prevented having an ideal isolation of the teams. The three facilitators from Conéctate al Conocimiento as well as the grade teacher offered mediation of the Cmaps construction. Considering the grade teacher as another facilitator, there were, in general four facilitators for five teams, almost a one-to-one (facilitator – team) attention. It should be stressed out that the mediation was carried out according to what was described before (translation mediation). Once the Cmap_{pre} were finished, some of the teams were interviewed. The Cmap_{pre} were transcribe to CmapTools and saved with file names allowing for easy identification (for example: "Cmap_{pre} – Team 3 – 4A"), this process was performed by the Conéctate al Conocimiento facilitators. Having the Cmaps saved in CmapTools allowed for a more efficient manner of working when analyzing the Cmaps.

There was a one week interim between the construction of Cmap_{pre} and the initialization of the Electrical Circuits project. The facilitator of Hagamos Ciencia project, Roberto Garrido, also gave his support. He is the person in charge of carrying out the inquiry experiences with the learner teams. Great stress was put into the

[4] In fact, it has been programmed to apply this methodology in other schools in order to keep on improving the model and take advantage of the integration of two important Panamanian strategies: Conéctate al Conocimiento and Hagamos Ciencia..
[5] Taken from Learning How To Learn (Novak, Gowin)
[6] Parking lot of concepts used to build Cmap_{pre}: Electricity, battery, light bulb, wire, security rules, home electrical appliances, energy source, pile, electrocute.

matter of keeping the teams for the inquiry experiences the same as the ones that built the $Cmap_{pre}$, aside from some variants; it was possible to keep some degree of control in this regard. After the 16 lessons from the project were covered (approximately 2 months later) [7] the Cmaps of the post experiences ($Cmap_{post}$) were built. The original conditions created during the construction of the $Cmap_{pre}$ were kept for the second session, the same teams, the same focus question, the same time was given, and the mediation kept on being only on translation on the part of the 4 facilitators. The main difference in the case of the $Cmap_{post}$ construction was that it didn't began with a blank page, the learners were given the $Cmap_{pre}$ and asked that, based on all that they had learned in the Electrical Circuit project, they make modifications to the ideas already stated on the $Cmap_{pre}$. Essentially what was done was a re-working up of the Cmap and a contrast between previous knowledge and new learning.

3 Results/ Analysis of $Cmap_{pre}$ versus $Cmap_{post}$



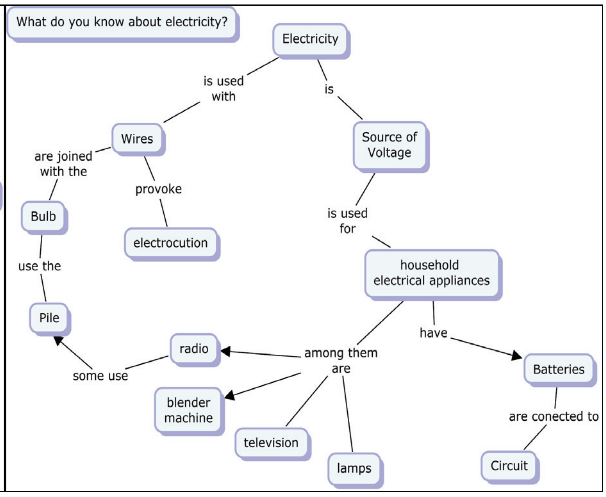


Figure 4: Example of $Cmap_{pre}$ and $Cmap_{post}$ built by a group of learners, they show some previous ideas they had about the question addressed.

3.1 Treatment by sets of propositions

We defined a set, denoted $\{Cmap_{pre}\}$, composed by all propositions generated in all of the $Cmap_{pre}$ and a corresponding set, $\{Cmap_{post}\}$, made up of all propositions generated in all of the $Cmap_{post}$. This allowed us to follow the evolution of the propositions. With the help of CmapTools, propositions were exported as text (properly identified), and transferred to a spread sheet which would help recognize, classify and filter the propositions. Propositions were classified in two categories: "deep" (d) and "superficial" (s) propositions.[8]

Table 1 shows the results obtained for the sets $\{Cmap_{pre}\}$ and $\{Cmap_{post}\}$.

Set	Total generated	Deep propositions	Superficial propositions	Percantage of Deep propositions	Percentage of Superficial propositions
$\{Cmap_{pre}\}$	288	89	199	30,9%	69,1%
$\{Cmap_{post}\}$	251	101	150	40,2%	59,8%

Table 1. Total number of propositions generated, deep propositions, superficial propositions, and percentages of each of these relative to the total generated. Sample included 15 $Cmap_{pre}$ and 15 $Cmap_{post}$

[7] *During the time the experiences were carried out, some 2 lessons per week, the learners kept on receiving their regular classes, during which the teachers kept on reinforcing the construction of Cmaps.*

[8] Criteria used to determine "depth" of propositions are the following:

a) *Proposition seek causes or effects in the relationship between concepts.*
b) *Proposition not limited to describing or enumerating concept attributes.*
c) *Proposition highly relevant and explicative within the context of the Cmap (in this case, electrical circuits).*

Propositions that do not comply with all of the above, are considered "superficial."

As the table makes plain, these results indicate a greater proportions of superficial propositions for both sets of Cmaps. Nonetheless, there is a decrease in the second map relative to the first, and this decrease is significant (P = 0.02).

Among the 288 propositions in $\{Cmap_{pre}\}$ and the 251 in $\{Cmap_{post}\}$, however, there were repeated propositions. In order to have a clearer picture of what actually took place in the group as a whole, it was necessary to identify repetitions, that is, propositions that are either identical or equivalent to one another. We found that the percentages of repeated propositions relative to the total number of generated propositions were 88.5% in $\{Cmap_{pre}\}$ and 90.0% in $\{Cmap_{post}\}$. The percentages were not significantly different. Doing this helped us interpret what kinds of propositions are repeated in greater percentage by the teams, in terms of deep and superficial propositions. Our results are given in table 2.

Set	Total repeated propositions	Deep repeated propositions	Superficial repeated propositions	Total distinct propositions	Deep distinct propositions	Superficial distinct propositions
$\{Cmap_{pre}\}$	255	75	180	33	14	19
$\{Cmap_{post}\}$	226	85	141	25	16	9

Tabla 2. Indicates the total number of repeated and distinct propositions, as well as the number of deep and superficial propositions in each subset.

As can be seen, overall there were many repetitions (this was to be expected, to a certain extent, given that all Cmaps dealt with the same topic), 255 in $\{Cmap_{pre}\}$ and 226 in $\{Cmap_{post}\}$. The following table shows the values in the form of percentages.

Percentage of deep repeated propositions in $\{Cmap_{pre}\}$	Percentage of deep repeated propositions in $\{Cmap_{post}\}$	Difference	Percentage of superficial repeated propositions in $\{Cmap_{pre}\}$	Percentage of superficial repeated propositions in $\{Cmap_{post}\}$	Difference
29,4%	37,6%	8,2%	70,6%	62,4%	-8,2%

Tabla 3. Percentages of deep and superficial propositions among subset of repeated propositions in $\{Cmap_{pre}\}$and $\{Cmap_{post}\}$.

Clearly, the percentages of superficial propositions were greater in both $\{Cmap_{pre}\}$and $\{Cmap_{post}\}$. However, we note that the percentage of deep propositions increased from $\{Cmap_{pre}\}$ to $\{Cmap_{post}\}$, with a corresponding decrease for superficial propositions. Neither of these changes turned out to be statistically significant.

3.2 Analysis of "condensed Cmaps"

In what follows we define two subsets of $\{Cmap_{pre}\}$ consisting only of distinct propositions of initial and final Cmaps. These sets will be designated $\{S_{pre}\}$ and $\{S_{post}\}$, respectively. We refer to these subsets as the "condensed Cmaps," since they are made up of all distinct propositions from $\{Cmap_{pre}\}$ to $\{Cmap_{post}\}$; these all repetitions have been eliminated. Thus, $\{S_{pre}\}$ is the condensed $Cmap_{pre}$ while $\{S_{post}\}$ is the condensed $Cmap_{post}$. It follows from table 2 that these maps are formed by 33 and 25 propositions, respectively. In table 4 we report the percentages of deep propositions in $\{S_{pre}\}$ and $\{S_{post}\}$, respectively. This difference does turn out to be significant at 10% (P = 0.10)

Percentage of deep propositions in $\{S_{pre}\}$	Percentage of deep propositions in $\{S_{post}\}$	Difference
42,4%	**64,0%**	**21,6%**

Table 4. Comparison of percentages of deep propositions in $\{S_{pre}\}$ and $\{S_{post}\}$.

4 Discussion

4.1 Of the results

In this study, entire sets of Cmaps needed to be handled and analyzed, in such a way that would reflect, quantitatively, whether there had been any changes subsequent to the project's activities. For this reason, an entirely new analysis methodology had to be developed (this was, in fact, the main purpose of the study) These new mechanisms, however, require validation, for it is not clear whether they constitute a valid way of determining the learning that took place among the students participating in the *Hagamos Ciencia* Project. This remark applies equally to the criteria we chose to determine the depth of a proposition. Having made this caveat, we proceed to discuss the implications of our results.

Our results indicate that among the total of propositions generated, superficial propositions predominated in both Cmaps (69,1% and 59,8% versus 30,9% and 40,2%). However, the change in the percentage of deep (and superficial) propositions between the initial and final Cmaps was significant. We believe this may have been a consequence of the inquiry activities carried out by the students. However, in training the students to use concept maps, we spent much time emphasizing rigorous thinking in order to construct propositions. Thus it is also possible that in some measure concept mapping may have contributed to the increase of deep propositions observed between the two Cmaps.

Another interesting result was that the 15 teams participating in the study coincided in (repeated) a large percentage of their propositions, both in the initial (88,5%) and the final (90,0%). (These values were not significantly different.) In a sense, this is not entirely surprising, since the subject matter was the same for all teams. More important is to notice that the percentages of deep and superficial propositions among the subset of repeated propositions were practically identical as the percentages in the complete set of propositions.

In spite of the fact that one cannot assure that a condensed map accurately reflects the joint knowledge of the teams, it is nonetheless a first approximation to an evaluation of a group of concept maps, which attempts to project itself as the group's collective knowledge. Clearly, it is necessary to validate the use of this form of condensed maps as truly reflecting group knowledge.

In considering the two condensed Cmaps, that is, the maps composed of the 33 and 25 distinct propositions from $\{Cmap_{pre}\}$ and $\{Cmap_{post}\}$, respectively, we focused our attention on the percentages of deep propositions. These changed from 42,4% and 64,0%, which is a significant change at 10% ($P = 0,10$). Once again, these values may reflect an impact of the *Hagamos Ciencia* activities in the students' knowledge. At the same time, the fact that concept maps were used to measure this knowledge, and that in training students in concept mapping, facilitators required students to think carefully and analyze various topics, we can not ignore the possible influence of this methodology upon the students.

4.2 Of the inconveniences:

Among the limitations that can be pointed out during the implementation of the model there are:
- The teachers had preconceptions about the Cmaps very different from the ones proposed by Conéctate al Conocimiento (Miller, 2006) that is, they didn't know about the construction of Cmaps based in propositions, nor the reasons why building them in this manner provide for knowledge representation and construction.
- The little time allowed for the person-to-person training. This happened because the teachers could not stop their daily educational activities, so the spaces to reinforce the training were very limited.
- The indiscipline in the groups of learners at the start of the sessions. This particular school is located within a community that presents several social problems which have a direct effect on the learners' behaviour and attitude. However, notwithstanding the issue just presented, the apprentices were enthusiastic enough with the project that the indiscipline lowered.
- The excessive time that passed between the reinforcing sessions and the construction of the Cmaps mediated by facilitators from Conéctate al Conocimiento. It was very difficult to stay close to the learners during the process. This task was entrusted to the school teachers, who should continue the training process with the learners.
- The issue that the interviews could not be used as a reliable source for contrasting the Cmaps, this was due to the lack of training in performing interviews.

5 Conclusion

This article presents a novel methodology, based on concept maps, for evaluating the acquisition of collective knowledge in science by a group of students working in teams, in the context of a scientific inquiry school project. Our results suggest that the model may be useful for determining group knowledge acquisition. However, based on our experience, several aspects of its implementation need improving, such as, adequate utilization of interviews, and the making sure that concept maps truly represent the state of learners' knowledge. Moreover, the model of data analysis requires validation; further studies need to be conducted to establish its validity.

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CONCEPT MAPS: A STRATEGY FOR THE DEVELOPMENT OF TECHNICAL REPORTS ON INDUSTRIAL ENGINEERING PROBLEMS

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Abstract. In this article we present a study case on the use of concept maps as a strategy for the development of technical reports on industrial engineering problems. These problems occur in complex, multidisciplinary environments that require the application of technical and social systems knowledge which is analyzed by an engineer in order to propose effective and efficient solutions. This case seeks to contribute to the development of engineers' skills through the construction of answers to investigative questions, based on a review of appropriate literature. To validate this contribution, the performance of students in the construction of these reports and concept maps was analyzed. A tool for measuring the students' perception of the utility and ease-of-use of the concept maps was also designed. The performance and perception results evidence the utility of the concept maps as a strategy for handling industrial engineering problems.

1 Introduction

With the purpose of contributing to the integral development of the industrial engineer's skills in the organizational field, a group of teachers and researchers designed the course Systemic Thinking in Organizations (PESO - *Pensamiento Sistémico en las Organizaciones*). This course is part of the Organizational Management module which seeks to provide industrial engineering students with enough resources to diagnose, design and structure different organizational systems. The PESO course expects students: (a) to understand the evolution of organizations; (b) to develop capacities for observing different organizational dimensions; (c) to know and apply systemic methodologies in order to observe and intervene in organizations; and (d) to develop competence in written expression, oral expression and research. These objectives are pursued through the activities that can be seen in the concept map of the PESO course (Figure 1).

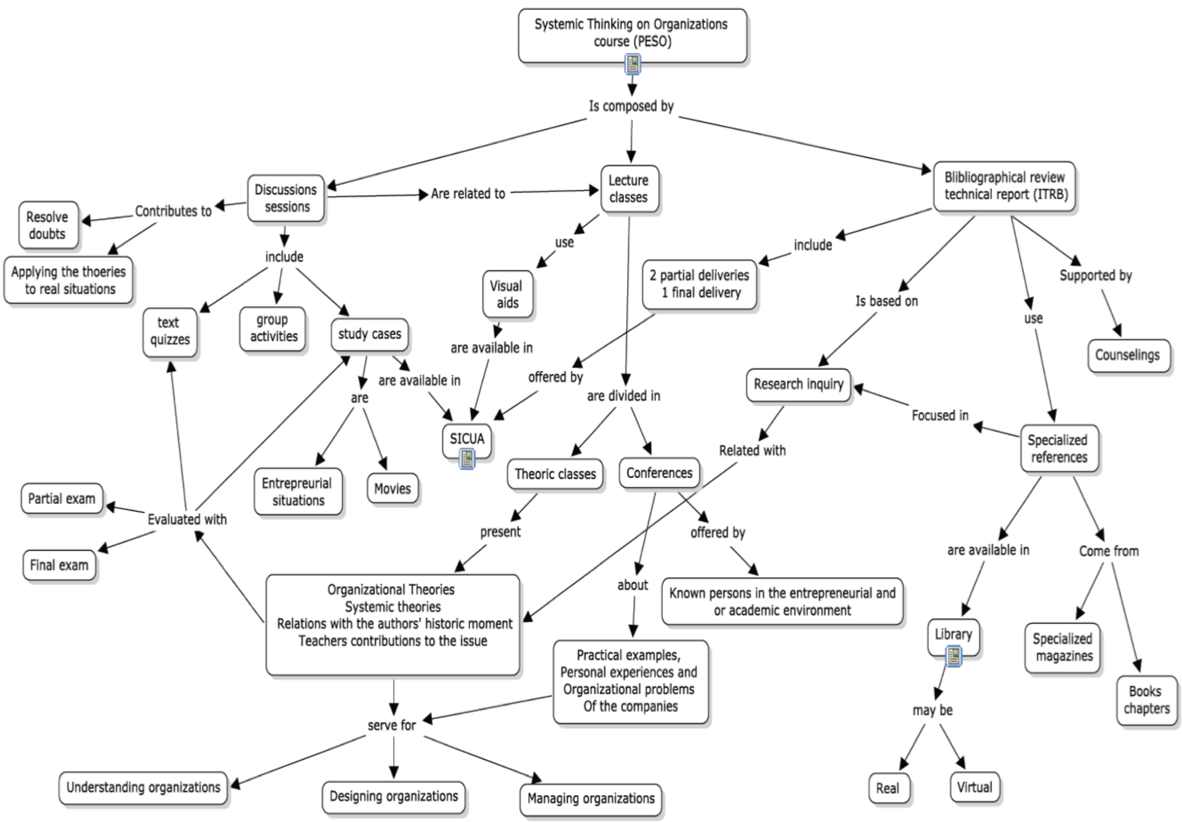

Figure 1. Concept Map of the PESO Course.

In order to attain the proposed objectives, particularly that related to the development of research, written expression and oral expression competences, a team of teachers and researchers have designed a tool called the Bibliographical Review Technical Report (ITRB - *Informe Técnico de Revisión Bibliográfica*). This is a report that seeks to strengthen the capacities of research and the approach to a specific situation from an engineer's technical perspective. It addresses a research enquiry related to the topics covered throughout the course and one of the teachers functions as a counselor for the students. It is executed in an entirely professional manner and has particular characteristics:

- it must be developed in two partial deliveries and a final delivery
- it must include an introduction, development and conclusion
- it must contain a definite number of words
- it must contain a definite number of references
- it must include a concept map of one of the investigated references and the different stages of the ITRB.

Each teacher posits a research enquiry relating to his/her sphere of interest and according to the investigation guidelines. The students have the opportunity of choosing one such enquiry and investigating it throughout the semester. Figure 2 displays an example of investigation topics suggested by the professorial team.

Research Topics (a brief list) **Examples of Research Questions (2007)**

T1: Corporate Strategy
- How does the Balanced Scorecard contribute to the improvement of an organization's strategic capacity? (A. Reyes)
- How do we develop a systemic process of stakeholders' identification? (J. Romero)

T2: Strategic Planning
- Can the evolutionary models approach the strategic planning processes in an organization properly? (C. Olaya)
- How do we develop a systemic process of management control? (C. Ramírez)

T3: Information Technologies
- How do we develop a systemic process of information technologies adaptation in an organization? (R. Hernández)
- How does the use of IT support the knowledge production in an organization? (W. Flórez)

T4: Organizational Learning
- How do we develop a systemic process of organizational learning? (J. Bermeo)
- How do we develop a systemic process of collaborative work? (R. Barros)

T5: Knowledge Management
- How do we develop a systemic process of intangible activities measurement? (W. Flórez)
- How do we develop a systemic process of knowledge production? (J. Cruz)

Figure 2. An example of Research Questions for the ITRB.

2 Theoretical Background

Given that one of the objectives of the PESO course is for students to develop competence in written expression, oral expression and research, it is necessary to justify the choice of technical report production as the right method to accomplish this objective. It is also important to clarify why the use of concept maps functions as a strategy to produce technical reports that supply theoretical solutions to common industrial engineering problems. Below are some considerations in support of these choices.

2.1 The ITRB as a tool for the development of communication and research skills

We consider that the ITRB enhances the identification, formulation and resolution of engineering problems, according to the ABET abilities proposal (ABET, 2003). Furthermore, the production of the technical report influences the development of written communication abilities. Additionally, the ITRB helps with the development of creative solutions to industrial engineering problems, through the understanding of the impact of these solutions and use of the necessary techniques to approach these problematic situations, as proposed by the National Academy of Engineering (NAE, 2004). Finally, in the development of the methodology for writing technical reports, the proposal made by Ashby (2000) was taken into account, especially with regard to the particular elements to be included in such reports. This implies a standardized review of the communication and research abilities observed in the students' ITRB.

Figure 3 highlights the different techniques used in the development of the ITRB that support the development of analytical and communicational abilities. This analysis is based on the proposals of the National Research Council (Bransford & Council, 2000) in the book *How People Learn*.

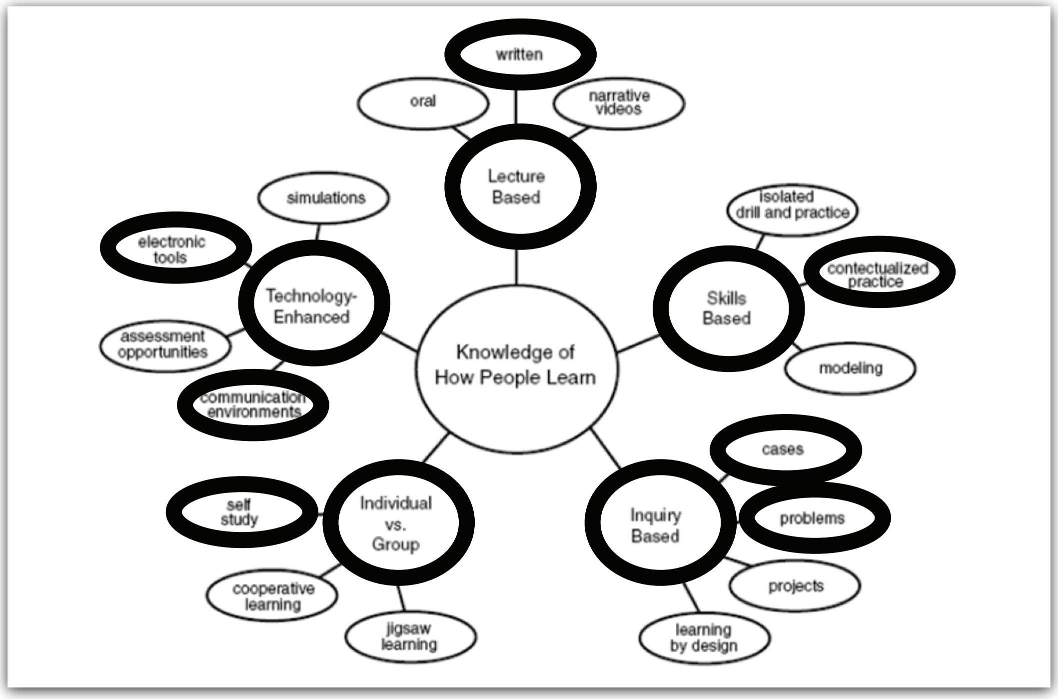

Figure 3. Knowledge of how people learn. The techniques included in the development of the ITRB are highlighted. (Adapted from Bransford & Council, 2000.)

2.2 Concept maps as a useful tool for the analysis of technical articles an approach to the research enquiry

After justifying the use of technical reports, we need to clarify the use of concept maps as a strategy for the production of these reports. First, the concept maps are graphic tools designed to organize and represent knowledge. Concept maps include concepts, relations between concepts and their hierarchy (the most general ones are placed above the less general) (Novak & Cañas, 2006).

Additionally, the concept maps become a useful tool for the analysis of technical articles since, according to Novak & Cañas, the concept maps are instruments that serve to organize and represent knowledge (Novak & Cañas, 2006). The student not only finds the most relevant concepts in the reading of the references but also generates semantic units related to the research enquiry. This articulation is facilitated through the construction of a general concept map which not only incorporates the most important concepts of the previous reading but also requires the construction of the interrelation between these concepts.

Two valuable characteristics of the concept maps in the analysis of technical articles are: (a) placing in a hierarchy the most inclusive concepts of the analyzed article (Novak & Cañas, 2006); and (b) a necessary element in the production of a concept map is the identification of a focus question (Novak & Cañas, 2006) that makes the student question the purpose of the author at the moment of writing the article and facilitates the relation with the research inquiry.

The group formed by (a) the research inquiry (focus question) and (b) the concept maps of the references generates the *context*, which is understood as a domain of knowledge that guides and defines the hierarchical structure of the general concept map (Novak & Cañas, 2006). Additionally, in the creation of new knowledge, the crossed links often represent creative leaps by the knowledge producer (Novak & Cañas, 2006). This additional element offers the possibility of generating creative leaps in the approach to an answer to the research enquiry.

Meaningful learning can easily lead to the generation of creative productions (Novak & Cañas, 2006), because generating a proposal to the research enquiry requires the students to have a relevant and well-structured knowledge base. The ability to construct an approach to a research enquiry in engineering based on the review of technical articles could hardly be obtained though mnemonic learning.

Finally, the production of concept maps facilitates examination of the assumptions that surround the statements of the authors of the particular references and helps to validate its integration in the answer to the enquiry. The concept maps encourage the process of reviewing and evaluating the assumptions. Several authors state that the concept maps are a useful tool not only for learning but also for evaluation: they are effective for identifying both the valid and invalid ideas that the students state in their approach and they facilitate review of the works delivered (Mintzes, Wandersee, & Novak, 2000; Novak, 1990; Novak & Gowin, 1984).

The evidence adduced above confirms that concept maps are a useful strategy for the analysis of technical articles and the construction of an approach to a research enquiry, processes that take place in the elaboration of the ITRB.

2.3 Production process of the ITRB and the concept maps

The purpose of the ITRB is the construction of an answer to a research enquiry related to common industrial engineering problems. In order to generate this answer an approach is constructed following these steps:

- choice of a research inquiry about an organizational issue
- review of literature specialized in the issue (search and documentation of pertinent sources)
- making concept maps of the articles
- making a concept map of the specific answer to the research enquiry
- composing the technical report that answers the research enquiry
- restarting the process twice, beginning with step 2, until the achievement of a third (and final) delivery of concept maps and a technical report at the end of the semester.

The evaluation criteria comprise the evolution of the three iterations of ITRB. In this evolution the students have to develop a report and a concept map, both for the research question. The research question is evaluated in terms of its consistency and coherence. According to these criteria the concept map and the report are evaluated in each one of the iterations.

It can be seen that the production process of the ITRB is dynamic and the construction of the concept maps is iterative in these activities. These iterations were designed so the concept maps would work as a strategy to facilitate the production of the ITRB. Specifically, the concept maps are a tool for:

- learning the technique of representing a knowledge that has been read – analysis of technical articles
- reflecting an acquired knowledge in a specific issue – approach to the research inquiry
- organizing information and synthesizing the acquired knowledge
- evaluating the learning process of a student in a specific issue

Figure 4 shows the relation between the activities that involves the production of the ITRB and the use of concept maps as a tool for supporting the ITRB production process.

3 The study case

Throughout the year 2007, 660 engineering students (in the second year of their careers) took PESO course and, consequently, participated in the production of ITRB and concept maps as support to this process. In order to evaluate the achievement of the proposed objectives (Figure 4) two variables were taken into account: perception and performance. Next, we explain each one of the measuring instruments.

3.1 Students' Perception

Our interest consisted in evaluating the perception of the student in term of ease of use of the concept maps, as well as the utility of this tool. The "ease of use" was related to the ease to approach technical reports through concept maps. The utility was defined in function of the concept maps usefulness for:

- understanding the proposal of the authors
- the main posing of the chosen inquiry
- the choice of key concepts (general and particular ones) for solving the inquiry
- finding relation between the key concepts
- the coherence between the proposals of the authors and the answer to the research inquiry
- validating the consistency between the technical report and the research inquiry

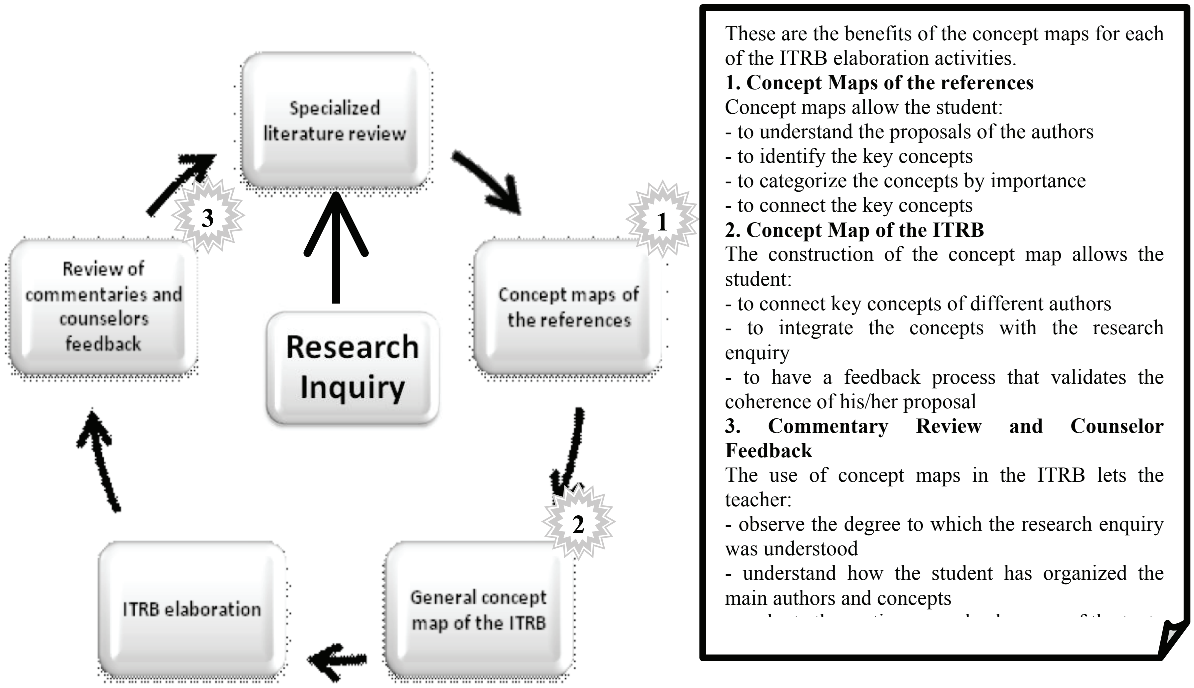

Figure 4. The ITRB elaboration process and its relation with the use of concept maps.

In order to evaluate these perception variables a survey was applied during March 2008. The survey was sent by e-mail to all the PESO students of 2007 (660). The rate of response was 28%. The results, questions and rate of response are shown in Chart 1.

The first six questions were intended to evaluate the perception that the students have regarding the utility of the concept maps, whether it is in terms of representing a text (question 1), reflecting acquired knowledge related to a specific issue (questions 2, 3 and 4), information organization and knowledge synthesis (questions 5 and 6). The results obtained show that the students perceive that the concept map is useful to assist with the production process of industrial engineering technical reports, taking into account each one of the described purposes.

Question 7 related to the ease of use of the concept maps tool. Once again, a large percentage of students rated this aspect positively (67% rated it 4 or 5).

Questions 8 and 9 related to the perceptions of the students regarding the use of this tool in other contexts. A total of 76% of the students have used concept maps in other projects. Additionally, 91% of the students think that making concept maps is useful to approach common engineering problems.

Another factor that complements these perceptions is student opinion expressed in the university surveys at the end of the semester. The students evaluated the ITRB activity as a practical and useful process for the course. Some students even suggested that this process could be replicated in other courses or used in the final research project at the end of the industrial engineering course. Professorial staff also recognize concept maps as a useful tool, both for them and for the students (see Figure 4).

3.2 Students' Performance

Student performance was evaluated by the measurement of each delivery against the criteria described in section 2.3. It is important to observe that the iteration process of ITRB includes the evolution of the report and the concept maps about the research question. The measurement grades went from 1 to 5 (5 being "excellent"). Figure 5 shows the mean grade evolution of the ITRB for the 184 students who answered the electronic survey. It can be seen that the ITRB evolves in the three deliveries (significance difference of means with a p-value under 0,001, assuming equal variances).

Rank: 1= least useful, 5=most useful					
Questions	**1**	**2**	**3**	**4**	**5**
1. The concept map of the ITRB was useful for understanding the proposals of an author in reference to the research enquiry's issue (concept map of the references)	5%	5%	26%	35%	29%
2. The concept map of the ITRB was useful for conceiving the main statement related to the research enquiry	3%	9%	21%	43%	24%
3. The concept map of the ITRB was useful for determining which were the key concepts leading to answer of the research enquiry	1%	5%	25%	36%	33%
4. The concept map of the ITRB was useful for finding relations between the key concepts of the authors in relation to the research enquiry	1%	8%	24%	33%	34%
5. The concept map of the ITRB was useful for achieving coherence in the relation between the authors and the research enquiry	3%	11%	23%	38%	26%
6. The concept map of the ITRB was useful for validating the consistency between the main statement, the relations between the authors' concepts and the research enquiry	2%	12%	19%	43%	25%
Rank: 1= least easy, 5=most easy					
Question	**1**	**2**	**3**	**4**	**5**
7. The development of concept maps is an easy to use tool for the approach to technical reports	1%	8%	24%	38%	29%
"Yes" or "No" questions					
Questions				**YES**	**NO**
8. Have you used concept maps in contexts different from the ITRB?				76%	24%
9. Do you think the production of concept maps for approaching common engineering problems is useful?				91%	9%

Chart 1. Survey on perceptions (utility and ease-of-use of the concept maps as support to the production of technical reports in engineering)

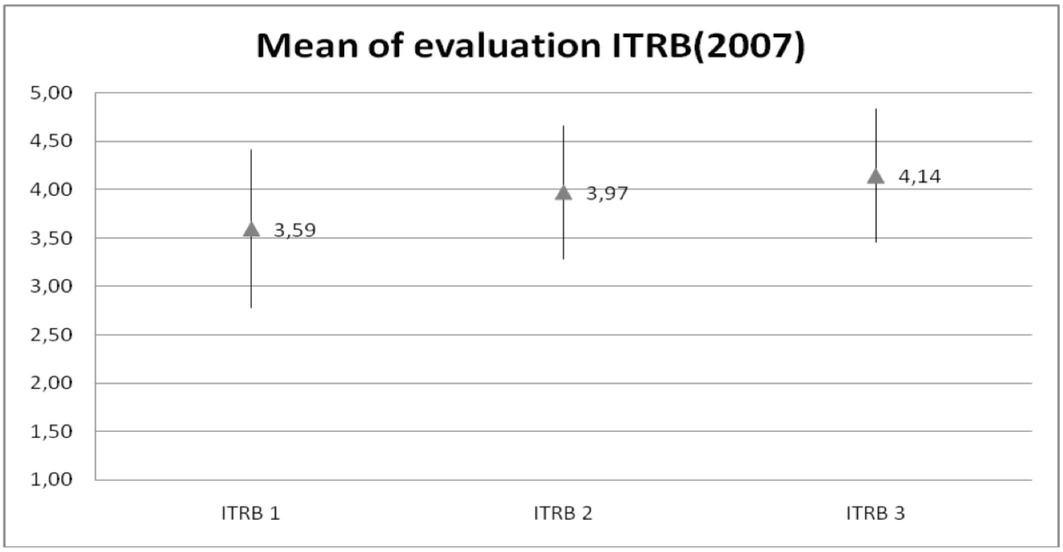

Figure 5. Mean and standard deviation obtained in the evaluation of the three deliveries of the ITRB.

One example of concept maps developed by the students in their ITRB is shown in Figure 6. In this concept map we can observe the improvement in the process applied to the research enquiry. For example, it evidences the inclusion of new concepts and relations, and the increment of these items through the deliveries. A particular analysis that could be developed in a future study relates to the following question: to what extent does this increase of the number of concepts and their coherence with the research question improve skills for solving industrial engineering problems?

4 Final Considerations

This work has shown the contribution made by the production of concept maps to the approach to common industrial engineering problems seen in the PESO course. Some examples of research enquiries were presented as well as the steps in constructing technical research documents. Some indicators regarding the ease-of-use and the utility of the concept maps, in the opinion of the PESO students of 2007, were presented, together with the students' performance in the ITRBs.

The main conclusions of the perception survey indicate that 67% of the students consider the concept maps a useful tool to elaborate their ITRBs; and 67% think this tool is easy to use. An interesting element that generates research opportunities is the use of concept maps in other environments; as a matter of fact, over 70% of the students have used them afterwards in other learning environments. Additionally, the general student and teacher perceptions of the concept maps have been a useful tool to enhance the writing and reading skills of the students.

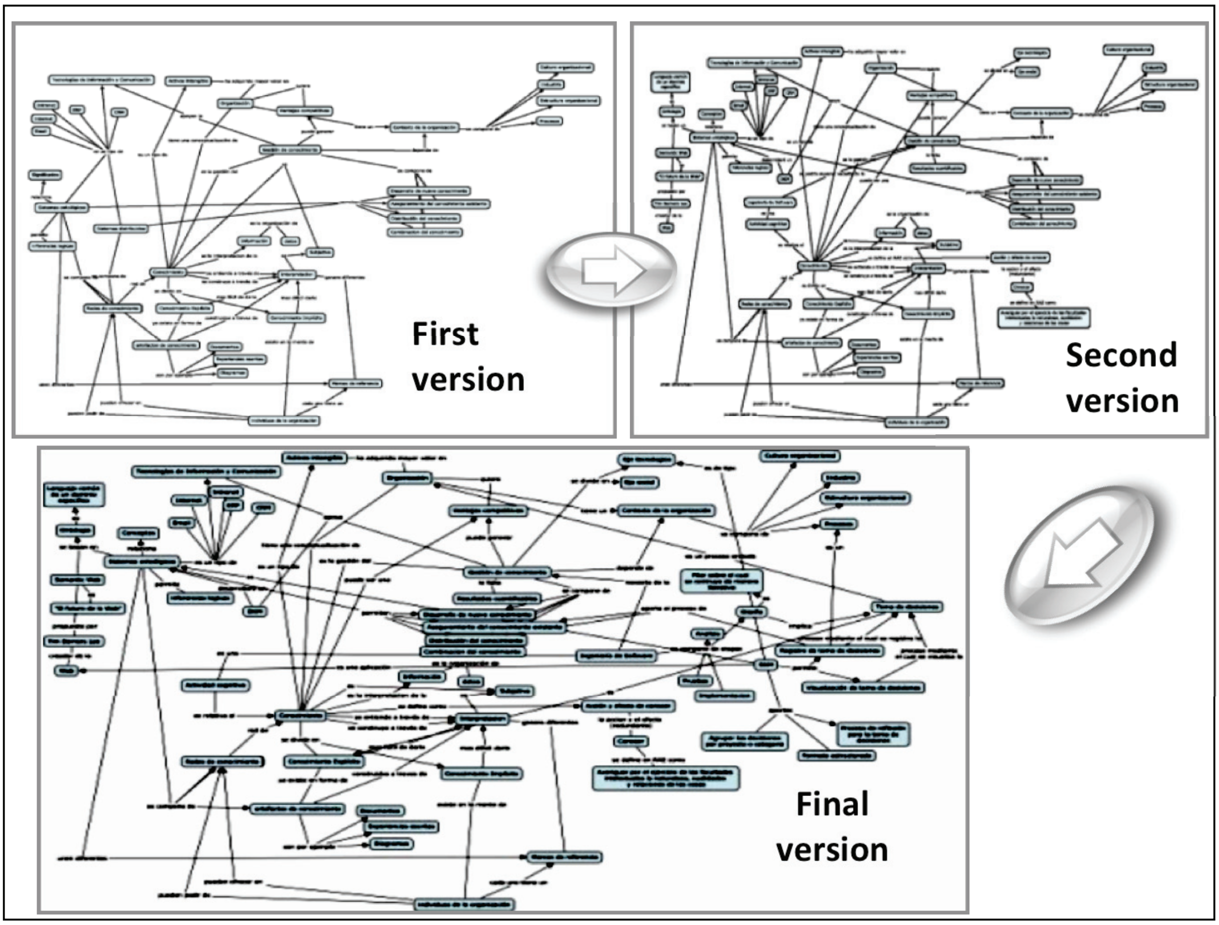

Figure 6. An example of a concept map developed by the students (Student: Jorge A. Quiroga, (jor-quir@uniandes.edu.co). Theme: How does the use of IT support the knowledge production in an organization? PESO 2007).

The method used in the ITRB (report and concept map) process is related to the proposal skills made by ABET (2003) and NAE (2004), specifically in terms of communication abilities and the identification, formulation and solution of engineering problems.

Impressed by the results of the concept maps used in PESO, some of the professorial staff of the Department of Industrial Engineering of Los Andes University have begun to use this tool in their courses. They and their students have also used concept maps in research projects.

Both the utility perception of the teaching staff and the results of the performance indicator of the students in the elaboration of the ITRB are evidence that the use of concept maps allows the students to integrate the concepts of several authors and to propose an answer to a research enquiry that simulates industrial engineering problems. Future works in this area include the following: (a) to explore and analyze how the number of concepts and connections evolve through the deliveries, and (b) to explore how this tool may be used in other aspects of the course (for example, in lectures and case studies).

5 Acknowledgments

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CONCEPT MAPS: A TOOL TO IMPROVE READING COMPREHENSION SKILLS OF CHILDREN WITH HEARING IMPAIRMENTS

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Abstract. Children with hearing loss who are inserted into the regular Panamanian School System tend to have academic difficulties, often due to low reading comprehension levels. Concept maps may be able to support hearing-impaired children to achieve better reading comprehension skills, by providing a means to improve their reading vocabulary, as well as helping them follow sequences of ideas present in ordinary texts. The structure of concept maps may facilitate reading comprehension because sequences of ideas, and relationships among them, are presented in a graphic format more accessible to deaf students. Since concepts are not repeated in concept maps, children with hearing loss become less confused than with ordinary texts, in which anaphoric expressions are commonly used. In this first exploratory study, comprehension of an ordinary reading passage was compared with comprehension of its transcription to a concept map format, both with and without illustrations. Results suggest that the concept map format leads to a greater understanding of the reading passage, as evidenced by the answers to questions posed by the researchers, as well as the questions posed by the subjects themselves, and their comments about the topic. The concept map format also awakened and maintained the deaf students' interest more so than the ordinary text format.

1 Introduction

In Panama, issues concerning the disabled have become a priority for the Government. Proof of this are public policies being put into practice focused on the well-being of children with special needs, and aimed at helping them achieve their full potential in today's world. In 1999, Panama's National Assembly, the country's legislative body, approved Law 42, a law affording equal opportunities to persons with disabilities. This law was subsequently regulated through Executive Decree 88 of 2002. In 2004, the government created the National Bureau for the Integration of Persons with Disabilities,[1] and in 2007 the First Disabilities Survey was conducted, with the support of the Office of the First Lady. This survey revealed an 11.3% prevalence of disabilities in the Republic of Panama, equivalent to approximately 370,000 Panamanians.

One of the main aspects promoted by Law 42 is *inclusive education*, that is, the inclusion of children and adolescents with disabilities within the regular educational system. The principle of inclusive education received international recognition and support during the World Conference on Special Needs Education, held in Salamanca, Spain, in 1994, and sponsored by UNESCO and Spain's Ministry of Education and Science. The shift away from special education obeyed, on the one hand, to criticism regarding the effectiveness of this type of education, and on the other, to a worldwide trend towards the establishment of human rights and the adoption of equal opportunity policies.

At the beginning of the 2006 school year, of the 2910 public elementary schools in the country (Departamento de Estadística del Ministerio de Educación, 2005), 175 had joined the National Plan for Inclusive Education (Ministerio de la Presidencia, 2006), integrating a total of 10,692 students with disabilities. Clearly, much more needs to be done here in Panama in terms of bringing schools to integrate children with disabilities into the regular education system. However, the situation in Latin America is not much better. Reports indicate that children with disabilities tend to be excluded from most countries' regular educational systems. In Colombia, for instance, only 0.32% of students at regular schools are children with some disability; one finds similar statistics in Argentina (0.69%) and Mexico (0.52%), while Uruguay and Nicaragua appear to have slightly higher percentages, 2.76% and 3.5%, respectively.[2]

Presently in Panama, people speak about "inclusion" when in actuality they mean "insertion." Insertion differs from inclusion in that disabled children are immersed in a regular school, without previous adequate preparation of teachers, family, classmates, or the disabled children themselves.

This study is circumscribed to one specific type of disability, namely, hearing-impairment. Hearing impairment is characterized by a partial or total deficit in the ability to perceive sound, which affects the person's communication in a fundamental way. Hearing-impaired children may develop different communication styles depending, among other things, on 1) the moment at which the hearing loss occurred, and 2) the type of rehabilitation process used.

[1] Known by its Spanish acronym SENADIS, *Secretaría Nacional para la Integración de las Personas con Discapacidad*.
[2] Source: www.risolidaria.org.pe

Among the 10,692 student with disabilities included in the regular school system, there are 767 with hearing loss. One problem that often arises when hearing-impaired children are included in the regular educational system is that they are classified according to the degree or severity of hearing loss, not by the competencies these children can potentially develop. Children may be passed from one grade to another based on their age, not on the abilities they have developed. This leads to a situation of low academic performance for hearing-impaired, particularly with regard to reading, writing, and general communication skills.

Paul (1996) summarizes much of what is known about reading vocabulary knowledge and reading achievement level for deaf[3] students. Research has shown that there exists a very strong connection between reading vocabulary knowledge and reading comprehension ability, though the exact nature of, or mechanism for, this relationship is still being debated. It is known, on the one hand, that good readers have large vocabularies. On the other hand, reading comprehension in children with hearing loss tends to be poor, owing among other language variables, to their limited vocabulary knowledge. Paul concludes that vocabulary instruction is necessary in order to help students with hearing loss to become independent word learners. However, he also points out that vocabulary instruction techniques such as the *definition-sentence approach*, which consists of looking up and/or writing down word definitions, along with using words in short sentences, are limited. This type of instruction leads to only partial word knowledge, which is often inadequate for discerning meanings, particularly in situations in which for alternative, figurative, or metaphorical meanings are involved. Thus, he recommends the *knowledge model* of instruction, a method that "promote[s] an in-depth knowledge of words" through "semantic maps... and other semantic elaboration techniques."

The above gives reason to believe that concept maps (Novak & Cañas, 2008) can be helpful in improving reading comprehension among children with hearing impairments, as well as hearing poor readers. In addition to the problem of a diminished vocabulary base, hearing-impaired children have difficulty in keeping track of sequences of ideas as they appear in ordinary texts. The structure of concept maps facilitates their comprehension since sequences of ideas are made evident. The fact that in a concept maps concepts are not repeated (no two concept nodes are identically labeled), children with hearing loss become less confused than with ordinary texts, where anaphoric expressions (references to linguistic elements previously mentioned) are used. Furthermore, the ease to search for and include images in concept boxes offered by programs such as CmapTools (Cañas *et al*., 2004) helps children with hearing disabilities to form mental images of concepts and visualize relationships. Sequences of ideas can thus be followed more easily and, we suspect, comprehension should improve.

To the best of our knowledge, no studies have been conducted in our country, Panama, that evaluate reading comprehension skills in deaf children or that explore the ways in which to improve these skills. The objective of this study is contribute to improve the quality of the education offered to children and adolescents with hearing loss, by improving these children's reading skills and their ability to learn meaningfully through the use of computer-mediated concept mapping tools. In so doing, we will propose new pedagogical techniques for working with concept maps with hearing-impaired students and for acquiring skill in using the computer program CmapTools, version 4.15.

2 Methodology

In this study we began to explore the effectiveness of concept maps as a tool to foster better reading comprehension skills. Given its exploratory nature, the study involved only one deaf child, a 13-year-old girl with profound hearing loss,[4] identified in what follows as S1. The subject at present uses no assistive hearing technology, though she did use a hearing aid up until 3 years ago.[5] She has significant communication difficulties, probably due to a rehabilitation program that included a hodgepodge of different communication techniques. As a result, S1 knows some sign language and has some ability to read lips, but is not fluent in the former, nor completely proficient in the latter. Consequently, getting ideas across to her often poses a great challenge. S1 graduated last December from 6th grade.

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[3] "Deaf" students are those with *severe* to *profound* hearing disabilities (Paul, 1996)

[4] Profound hearing loss corresponds to losses of 90 dB or greater. The person is unable to hear sounds such as the noise made by an airplane during takeoff.

[5] We suspect the reason she is not using it at the moment is related to her having entered adolescence, and thus being more sensitive about her looks.

The study was conducted by three facilitators of Panama's Conéctate al Conocimiento Project (Tarté, 2006) one of whom is a special education teacher, specialized in hearing and language. She knows both sign language and lip reading.

In addition to S1, two other children (S2 and S3), both with normal hearing, participated in the study. S2 is an 11-year-old girl, presently in 5th grade; she is a very good student. S3 is a 12-year-old boy, enrolled in 6th grade; he is an average student. The purpose of including these two hearing children was to have a point of reference against which to compare and interpret our results with the deaf subject. All three children attended schools incorporated to Panama's Conéctate al Conocimiento Project and thus were somewhat familiar with concept maps.

The study was divided into two stages described below.

2.1 *STAGE 1: Approaching concept maps*

The first part involved the researchers working with S1, the hearing-impaired student, in order to ascertain her degree of familiarity with and understanding of concept maps. This initial phase required two work sessions with the subject. The subject was asked to construct a concept map responding to the focus question "Who am I?" During the construction process one of the researchers, using the chat window available in the synchronous collaboration mode, asked the subject amplification questions to help broaden and deepen her map.

2.2 *STAGE 2: Reading comprehension of text versus transcription to concept map*

This stage included the actual research problem, namely, the comparison of reading comprehension of texts presented in the traditional format versus their transcription to a concept map, for hearing-impaired. By "transcription" we mean any concept map whose information content, proposition by proposition, is equivalent to that of the original text.

The deaf subject's reading comprehension was derived from her reactions to and comments about the reading material. A combination of indifference to the material (e.g., expressionless face, looking away from the screen, fidgeting, playing with styles palette), with no comments to researchers were interpreted as "no comprehension." On the contrary, interest in the material (e.g., curious expression, attention focused on the screen, following the reading with the mouse pointer), along with questions or comments made to the researcher about the material, were interpreted as "comprehension."[6]

Due to the fact that hearing-impaired students generally require more explanation time in order to understand correctly a given instruction, and in order not to bias the study as a result, the researchers had an additional work session with S1 during which she was introduced to the study's methodology.

S1 was presented with a short reading passage on the topic of "Vacation time," given time to read it, and then asked questions about it to test her comprehension. This text was presented as a Word document on a computer. Subsequently, S1 was given a concept map rendition of this text, given time to read it, and asked questions about it.

For the actual study, all three children were first provided with a brief reading passage on the subject of "Adolescence." The text (appendix A), an adaptation of Wikipedia's definition for *adolescence*, was given in printed form. The text contained a total of 87 words, 179 syllables, 4 main ideas, 15 key concepts, and 1 illustration (not shown). Afterwards, the subjects were presented on a computer screen with two transcriptions of the reading to concept map format: the first one included no illustrations (appendix B), while the second one included 9 illustrated concepts (appendix C). Subjects were given as much time as they needed to complete the readings. They were asked to indicate unfamiliar concepts after each reading.

3 Results

The results of the first part of the study showed that S1was indeed familiar with concept maps. With help, she was able to incorporate into her Cmap as propositions concepts that arose through questions posed by the

[6] We realize these reactions need not indicate a full comprehension, for they could also indicate puzzlement or only a partial understanding; however, given the communication difficulties of this particular subject it was difficult to make this kind of distinction.

researchers, questions such as: Where do you live? Where do you study? What do you like to eat? Where have you traveled to? What do you want to be when you grow up? What is your family like?

Having ascertained that neither concept maps nor computers were an obstacle for S1, and having gained her trust and cooperation, we moved on to the second stage of our study.

3.1 Comparison between traditional text format and concept map format

As explained above, during the second phase, subjects were to read a passage on adolescence presented first in text format. However, a preliminary practice session was conducted with the hearing-impaired student in order to make sure she had a full understanding of the instructions and the procedures. During this session, we noticed that S1 often became distracted from the reading task, as evidenced by 1) spending time altering style options of the Word document, such as font size, and highlighting the text in various colors; and 2) frequently looking away from the screen to observe her roundabouts. When she was done, she asked no questions, and made no comments about the text to the researchers.

When the same topic was presented in a concept map with no images, S1 demonstrated a certain amount of interest in understanding the map's content by pointing at concept nodes. Later, when presented with the illustrated concept map, she not only showed interest, but actually began to add to the map based on her vacation own experience. Confident that she was clear about what was to take place, we proceeded to present the adolescence text to all three subjects.

S2 and S3 took approximately 10 minutes to read the passage in text format, while S1 required 20 minutes. Table 1 (below) shows the concepts understood by each of the subjects after reading the passage first in text format, then in non-illustrated Cmap format, and finally, in illustrated Cmap format.

As the table makes plain, S1's recognition of concepts in the reading passage was quite poor. She made no comments about the passage, and when asked whether she had any questions, she pointed to key concepts like "adolescent" and "mind" and indicated she was not familiar with those words. When asked specific questions about the passage[7] (table 2), she was unable to provide concrete answers: she would reread the text, searching for the answers, or would look away into the distance.

S2 and S3, on the contrary, were familiar with most of the concepts in the passage, 12 and 9, respectively. Moreover, the hearing students understood 3 of the 4 main ideas contained in the text.

Turning to the transcription of the reading passage to the non-illustrated Cmap format of the, S1 required 10 minutes to read it. As before, she displayed little interest in the reading, asked no questions, and did not appear to relate the subject matter of the Cmap to that of the text previously read in the traditional format.

When the illustrated version was given to her, however, her attention was aroused. She focused intently on the screen, followed the connecting lines between concepts with the mouse pointer, and asked questions about the images she observed in the concept nodes. Interestingly, as she read from the map she focused more on the concepts than on the linking phrase, which she just passed over. She was particularly interested in the images associated to the concepts of "mind" and "changes in body weight and size," pointing out to the researchers that this has not yet happened to her or would not happen to her. She also pointed, with certain embarrassment, to the figure representing biological changes, questioning the researchers about it. In the end, S1 was able to understand 4 concepts through the illustrated concept map, for a total of 5.

As for the hearing students, after reading the non-illustrated Cmap S2 understood 2 of the 3 concepts she did not comprehend after reading the text; the illustrated map contributed no further understanding though. S3, for his part, was able to understand 4 additional concepts (of 6) after reading the non-illustrated Cmap; as with S2, the illustrated map made no further difference.

S3 noticed and commented that the Cmaps contained same information as the original printed text. Neither of the other two subjects gave any indication that they were aware of this connection.

[7] The 4 questions posed by the researchers referred to the 4 main ideas contained in the passage.

Comprehension of concepts from the reading passage “Adolescence”	Comprehension after reading text (regular format)			Comprehension after reading Cmap *without* images			Comprehension after reading Cmap *with* images		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Adolescence		✓	✓		✓	✓		✓	✓
Development stage		✓			✓	✓		✓	✓
Childhood	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adulthood		✓	✓		✓	✓	✓	✓	✓
Grow		✓	✓		✓	✓	✓	✓	✓
Biological change		✓			✓	✓		✓	✓
Mind		✓	✓		✓	✓	✓	✓	✓
Social life			✓		✓	✓		✓	✓
Intellectual maturity		✓			✓			✓	
Sexuality		✓			✓	✓		✓	✓
Weight increase		✓	✓		✓	✓	✓	✓	✓
Size increase		✓	✓		✓	✓		✓	✓
Hormonal secretions									
Environment		✓	✓		✓	✓		✓	✓
Latin					✓	✓		✓	✓
Total	**1**	**12**	**9**	**1**	**14**	**13**	**5**	**14**	**13**

Table 1. Comprehension of concepts after reading the passage in 1) traditional format, 2) non-illustrated concept map format, and 3) illustrated Cmap format. Shaded concepts are those represented by images in illustrated version of the Cmap.

QUESTIONS	Subjects’ answers after reading from text		
	S1	S2	S3
What does “adolescence” mean to you?	No concrete answer.	It’s a development stage, when one is growing and changing the way one is. One becomes an adult after a certain age. At 30 years, approximately. Biological changes cause changes in the way one acts and talks. These are changes in our weight and size, as the reading says. Mental maturity: one matures since one is a child.	It’s when a child becomes an adult.
What changes do you think take place during adolescence?	No concrete answer.	From adolescent to grown-up.	You grow and your size changes.
When do you think adolescence ends?	No concrete answer.	It ends when you finish your studies (school). More or less around 28 or 29 years of age.	It ends when you become 18 years old.[8]
Do you think your adolescence has begun? Why?	No concrete answer.	No. Because I am still a child. I have not changed certain physical and mental things, and things about school.	I don’t know. I’ve never stopped to think about that.

Table 2. Answers provided by subjects after reading the passage in text format.

[8] In Panama, a person is legally considered an adult at 18 years of age.

4 Discussion

The results presented in the previous section suggest that illustrated concept maps, unlike non-illustrated ones, may provide a means to foster reading comprehension among deaf students, even (or perhaps particularly) those with very limited vocabulary and serious reading comprehension limitations.

When presented with the reading passage in ordinary text format, S1 recognized only 1 of a total of 15 concepts. Reading a transcription of this text to a non-illustrated Cmap format made no difference for this student. However, after reading the illustrated version of the same Cmap, she was able to comprehend 4 additional concepts. It is important to point out that all of these were among the illustrated concepts in the map, and all had clear, unequivocal pictorial representations.

Nonetheless, this still leaves four more illustrated concepts that S1 did not comprehend. We believe that this may have been the result of an inadequate choice of images. For instance, the concept "biological change" was represented by the nude body of an adolescent girl and boy. However, this image is static and does not imply a transformation. Another problem arose with the concept of "size increase," which mistakenly was represented by the same image as "weight increase."

These problems may be overcome in part by a proper choice of illustrations. However, using CmapTools it is also possible to include other forms of visual resources, such as videos, applets, Web pages, etc. In some cases, these might help clarify those ideas which a single snapshot may not be able to.

These difficulties notwithstanding, we consider that illustrated concept maps can be a useful tool to facilitate reading comprehension and content retention for children with hearing disabilities. One reason is that children with hearing loss have trouble following sequences of ideas in ordinary texts. The structure of concept maps, in which relationships are made explicit, can help overcome this difficulty. Moreover, the fact that concepts are not repeated in concept maps, avoids the confusion resulting from anaphoric expressions commonly used in ordinary text.

Based on S1's positive reaction and involvement with the illustrated concept map, it would also seem that this format is in some sense more "inviting" to deaf students. Perhaps by its flexible, non-linear structure of overt relationships, these students are motivated to draw from their previous knowledge, contributing from to the reading from their own personal experiences.

With regard to the two hearing subjects, these too benefited from the transcription of the text to concept map format: 2 out of 3 for S2, and 4 out of 6 for S3. It must be pointed out, though, that one of the concepts neither S2 nor S3 understood from in the original text was "Latin." In the concept map, this was transcribed as "Latin language," which probably accounts for their subsequent understanding of it.

For them, however, the illustrations made no difference in terms of their comprehension of individual concepts or the entire passage. In fact, one of the students (S2) indicated that it was actually easier to read the non-illustrated concept map than the illustrated one. This may be related to the fact that they are older students, and may not be true of younger ones.

5 Conclusions

In summary, this study attempted to find out whether concept maps can promote greater reading comprehension skills, and thus, can contribute to improve the academic performance, and the personal and social development of students with hearing disabilities. The results of this exploratory study are encouraging. It appears the structure of concept maps, along with the visual props provided by illustrated concepts, may ultimately provide a richer context for hearing-impaired students to acquire and derive meanings from. Illustrated concept maps also awakened and maintained the deaf students' interest more so than the ordinary text format. This is would constitute a valuable side benefit for these children, who due to their condition, may easily become disengaged from a learning situation.

We plan to continue working with S1, helping her to improve her knowledge construction skill and her academic achievement through the use of concept maps. We also hope to continue research into the possible benefits concept mapping might have for hearing-impaired students.

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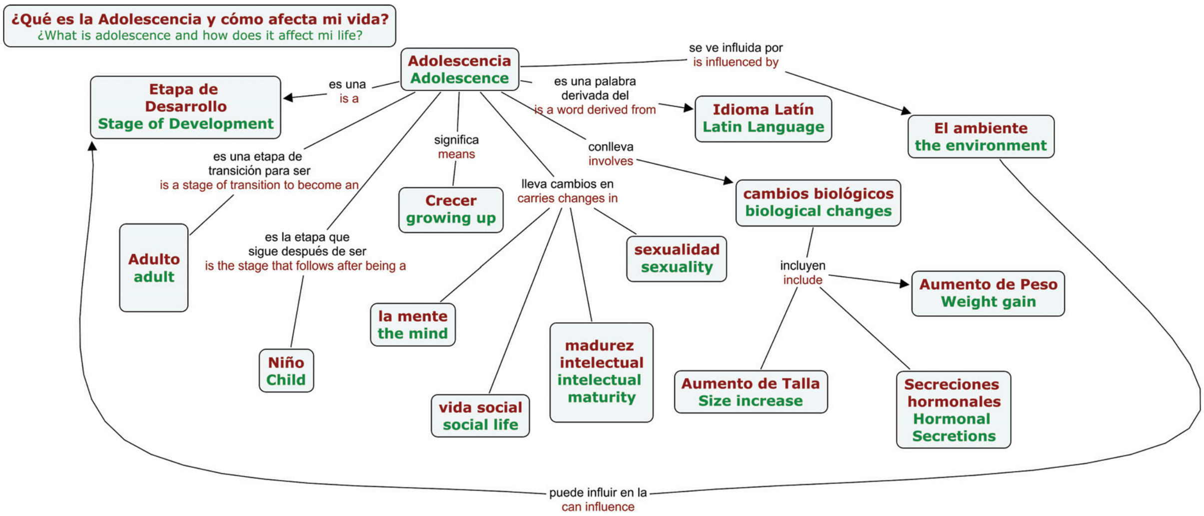
Appendix A: Reading passage on the topic of *adolescence* in ordinary text format.

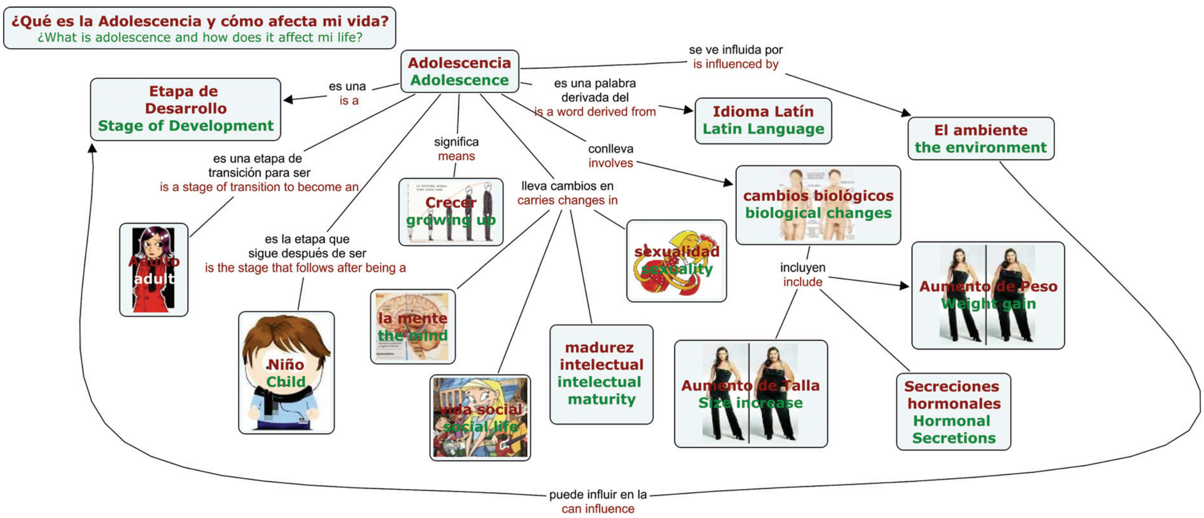
A**dolescence** is a development stage that comprises the passage from childhood to adulthood. (Idea #1)
The Word comes from the Latin *adolescere* which means "to grow." (Idea #2)
The transition that takes place is not only a biological change that includes changes in weight, size, and hormonal secretions, but extends also to the mind, social life, intellectual maturity, and sexuality.
(Idea #3)
This development of body and mind is related also to the environment. A good development is important to become a healthy adult. (Idea #4)

Source: Adaptation of definition of adolescence found in Wikipedia (http://es.wikipedia.org/wiki/Adolescencia).

Appendix B: Transcription of the text “Adolescence” to concept map format - non-illustrated version.



Appendix C: Transcription of the text “Adolescence” to concept map format – illustrated version.



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DESIGNING DEGREES: GENERATING CONCEPT MAPS FOR THE DESCRIPTION OF RELATIONSHIPS BETWEEN SUBJECTS

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Abstract. The Spanish University System is carrying out a convergence process towards the model proposed in the European Space for Higher Education. This involves, among other things, the redesign of all degrees and associated curricula. To achieve a coherent design of a degree we need to carefully analyze the relationships between subjects and the competences to be acquired by taking them. These relationships can be formalized using a complex directed graph, but using concept maps facilitates the understanding of these relationships. Due to the high number of concepts and relationships present in a degree, it is not possible to manually construct the concept maps. In this paper we describe a method and tool to automatically generate different concept maps from the raw data of a degree (subjects, competences, and different relationships between them), previously stored in a database. The generated maps will provide helpful information for Students when choosing learning itineraries, and for the School to assure the coherence of the curriculum.

1 Introduction

The Bologna Declaration (CRE, 1999) has fostered a number of changes in the Spanish University System, ranging from organizational aspects to learning and teaching methods. The convergence to the European Space for Higher Education involves, among other things, the redesign of all university degrees and associated curricula.

One of the novelties to consider when designing the new curricula is that they should be based on the acquisition of competences. Therefore, keeping in mind the professional competences a graduate should have, the subjects in the curricula must be directed towards the acquisition of these competences. On the other hand, each subject needs some previous competences of the students in order to understand the contents addressed.

With these relationships between previous competences, subjects, competences contributed by the subjects, and professional profiles, it is possible to establish a dependencies graph representing these relationships.

A quality curriculum will be characterized by a well-structured dependencies graph, where

- All previous competences needed are contributed by subjects already taken.
- All contributed subjects are useful for other subjects or for a professional profile.
- A given competence is not redundantly covered in more than one subject.
- All required professional competences are covered.

Analyzing the dependencies graph we can assure that these conditions are fulfilled, problems can be detected, and appropriate corrective measures can be taken.

2 The Degree Map

In the School of Computing Engineering of the University of Oviedo, the before mentioned dependencies graph of the current Degree in Computing was constructed as a previous step to design the new curriculum. For each subject in the current curriculum, the list of learning objectives has stated, as well as the degree competences associated to each learning objective, and the previous competences needed for the learning of the subject.

All this information was stored in a database. The following direct and indirect relationships, among others, can be extracted from the data:

- Subject - subject relationships.
- Previous competence – subject – contributed competence relationships.
- Competence – competence relationships.
- Competence – professional profile relationships.
- Subject – professional profile relationships.

Figure 1 shows the relationships to be studied. Where necessary, we will use different colours to clearly discriminate the concepts and to stress the level of dependency between some concepts.

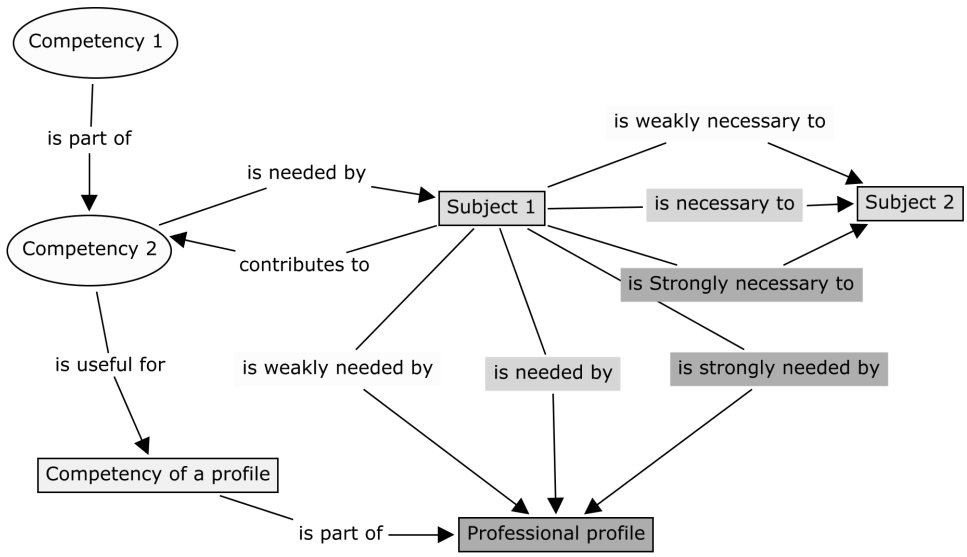

Figure 1. Relationships between subjects, competencies, professional profiles and their competencies

In each case, the meaning of the relationship is different. A subject *depends on* another subject, a subject *needs* a competence or *contributes* to a competence, a competence *is part of* another competence, or a subject *is needed* for a professional profile.

As the volume of data and generated relationships is high, it is necessary to have a graphical representation. A number of directed graphs were produced from the database. However, the comprehension of the graphs is still complex:

- The graphs are not easily to understand without a prior explanation of the meaning of the relationships.
- The graphs are not adequate for expressing more than one type of relationship in the same graph, where each edge can have a different meaning.

To solve these problems we propose to use concept maps, providing more meaning to the relationships and improving the understanding.

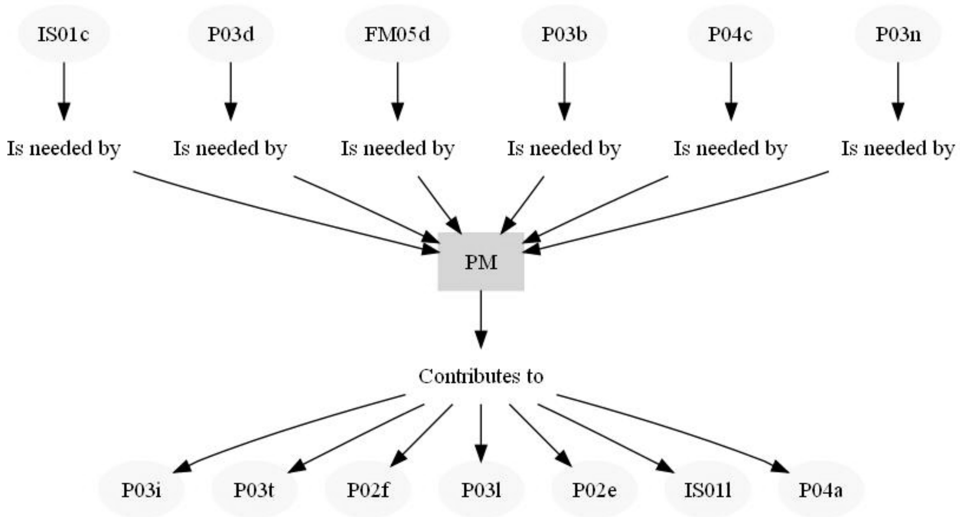

Figure 2. Previous and contributed competences of one subject

Each subject will have a concept map where the previous and contributed competences of the subject are shown. Besides, a concept map will be constructed relating the learning objectives with the associated competences of the degree. Another map will illustrate the other related subjects.

For instance, Figure 2 shows the competences required in order to take the subject "Programming methodology". The contributed competences are also shown.

Another interesting map can be studied in Figure 3, where the dependency relations between the subjects dealing with programming can be studied. The map shows not only the subject which must be taken first, but also the level of dependency. This map can be generated for all the subjects of the degree, for any subset of them or for only one subject.

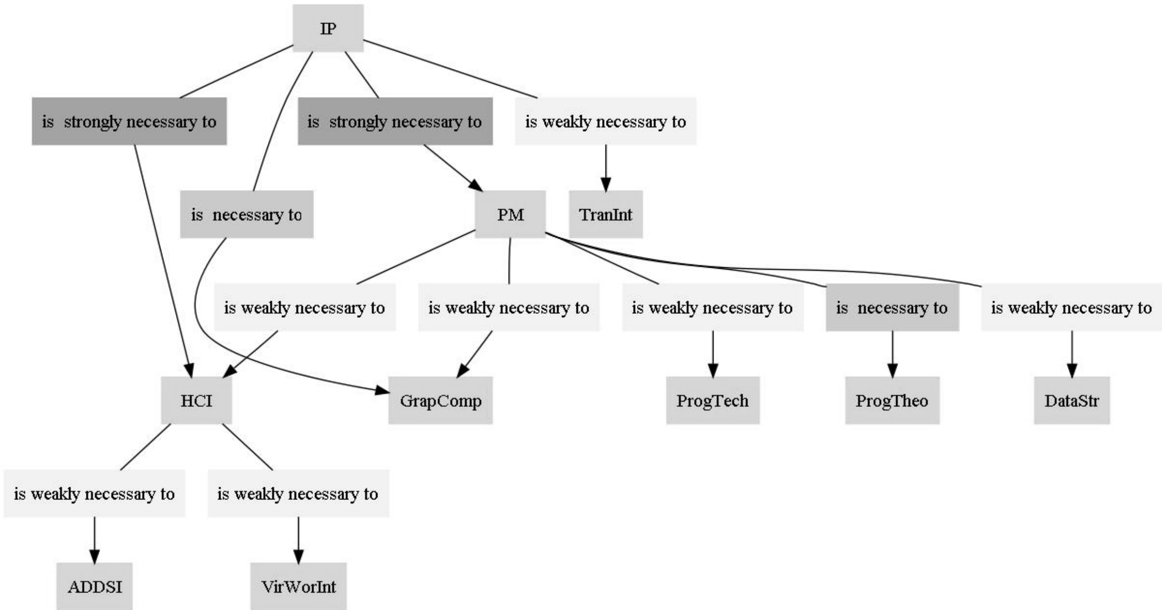

Figure 3. Dependency relationships between programming-related subjects

These maps are much clearer than textual representations or a traditional directed graph. With this representation it will be also possible to join all proposed maps in only one encompassing all relationships. Figure 4 shows the relationships between a set of subjects and with the corresponding professional profiles.

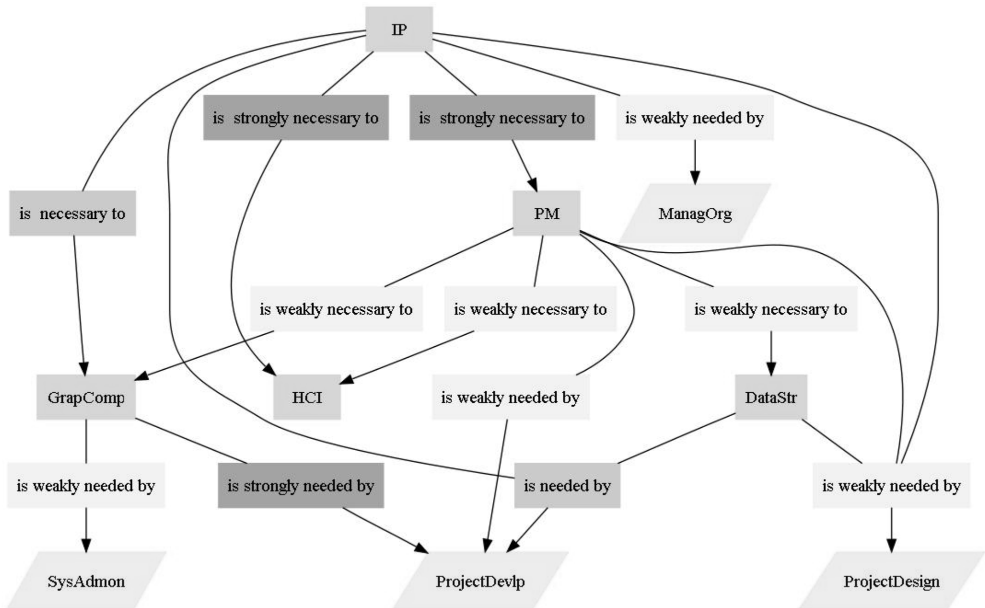

Figure 4. Map with several kinds of relations

Another type of map is needed to complete the description of the degree: a map relating the contributed competences of a subject to the professional profiles.

The set of these concept maps will form the Dependencies Map of the Degree (Degree Map). The Degree Map constitutes an important part of the documentation in the design of a degree.

2.1 Advantages of the Degree Map

The construction of the Degree Map, easily understandable by using concept maps, can be of great importance. Thus

- As it expresses precedence relationships between subjects, the complete Map helps the student with the selection of itineraries, and to decide when to take each subject, facilitating the learning process.
- As it contains all the dependency relationships, the map can be used to check the coherence in the design of the degree, avoiding gaps in competences not covered by any subject, competence overlapping, etc.
- Finally, the map is very helpful as documentation for the accreditation and certification processes of the degree.

2.2 Implementation problems

Due to the data volume involved, it is not feasible to manually construct the maps. It is possible to independently build the map for one subject, but the whole map relating all subjects and competences of the degree would be very difficult to set up. Therefore, an automatic tool to generate the complete map or any of its parts, from the data stored in the database was developed.

3 Generating Degree Maps

As mentioned before, the number of concepts and relationships involved really requires an automated tool to generate the maps from the raw data in the database. For example, in our computing degree there are 71 subjects, 314 subject competences and 1640 relationships between competences, subjects, and profiles existed.

The first step when generating a map is selecting the information to represent. The relationships of interest are:

- Subject - subject relationships.
- Previous competence – subject – contributed competence relationships.
- Competence – competence relationships.
- Competence – professional profile relationships.
- Subject – professional profile relationships.

Once the type of map is selected, and the required parameters (subject or subjects to visualize, type of relation to represent, etc.) a database query is build to select the data.

From this data a file representing the map is created and fed into the *graphviz*[1] (Gansner & North, 1999) application. *Graphviz* is a package of tools for generating graphical representations of graphs.

We had already used this tool to generate the initial dependency graphs referenced before. With this experience and, considering that concept maps are graphs after all, we also used it for building the concept maps.

Both the representation of the concept map (a graphic file in JPEG format) and the detailed description of the concepts involved (subject names, competences and profiles) are visualized in a navigable web page with linked maps. For example, from a map relating subjects it is possible to link to the map with the detailed description of a subject, and then to a map with relationships between subject competences.

[1] graphviz (short for *Graph Visualization Software)* is a package of open source tools, that can be downloaded from www.graphviz.org under the Common Public License.

As the time consumed for the generation of the graphic can be considerable (up to a minute for complex maps), a query cache is implemented so that a repeated query just uses the already-generated graphic.

3.1 Contributions of concept maps to the design of degrees

Generating concept maps to visualize the relationships between the different elements that characterize a degree has a number of advantages. These advantages are based on two basic facts:

- The utilization of concept maps integrates much information in the graphical representation without reducing clarity.
- Generating the maps from the database allows selecting the information of interest for each specific case.

The implemented system has been of great help with two of the fundamental concerns we looked for when initiating the construction of the degree map:

- The relation between subjects and between previous competences-subjects-contributed competences, expressed with the clearness provided by the concept maps, helps the student with the choice of his itinerary.
- The flexibility when reflecting the relationships between the elements selected by the user allowed the Dean and the Board of the School of Computing to analyze the design of the degree, and to discover some problems of coordination between subjects resulting in corrective measures.

3.2 Features to improve

We found some issues to resolve in future versions of the developed tool, and for subsequent studies.

The first drawback is that currently the maps are static. Modifications cannot be done on the map, but only through direct change of the database. Obviously, it is better to have some mechanism to graphically update the information.

The second limitation is that it is not possible to add additional “extra” information to the map, such as linking the subjects with its syllabus, the teaching staff, etc.; just the visualization of subjects and competences is possible.

4 Future Work

To enhance the system it is important to improve the interaction with the generated maps. We are working in two areas:

- Instead of generating maps in graphical format, it would be better to generate them in the format of CmapTools (Novak & Cañas, 2006). This would allow to use these tools afterwards to modify the maps, work collaboratively on them (Cañas et al., 2004), etc.
- Once the map is modified interactively, the changes should be automatically updated in the database for coherence reasons.

5 Conclusions

The usefulness of concept maps to express the design of the curriculum of a degree has been shown. Using concept maps visualizes clearly the dependency relationships between subjects, helping the students decide their itinerary in the degree in a coherent way. Besides, the design of the curriculum is facilitated by the assigning of competences to the subjects, uncovering possible inconsistencies. Concept Maps are also important in the phase of implanting a new degree, as the maps help establishing groups of coordination between subjects.

An automated tool to construct these maps has been developed, using information from a database storing the concepts and relationships between them. This enables the construction of different views according to different interests.

In short, this approach of applying concept maps to the design of a curriculum for a degree is original, and provides appreciable advantages for students, the School and the quality assurance of the degree.

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DEVELOPMENT OF A CONCEPTUAL STRUCTURE FOR A DOMAIN-SPECIFIC CORPUS

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Abstract. The corpus reported in this paper was developed for the evaluation of a domain-specific Text to Knowledge Mapping (TKM) prototype. The TKM prototype operates on the basis of both a combinatory categorical grammar (CCG) linguistic model and a knowledge model that consists of three layers: ontology, qualitative and quantitative layers. In the course of this evaluation it was necessary to populate these initial models with lexical items and semantic relations. Both elements, the lexicon and semantic relations, are meant to reflect the domain of the prototype; hence both had to be extracted from the corpus. While dealing with the lexicon was straight forward, the identification and extraction of appropriate semantic relations was much more involved. It was necessary, therefore, to manually develop a conceptual structure for the domain which was then used to formulate a domain-specific framework of semantic relations. The conceptual structure was developed using the Cmap tool of IHMC. The framework of semantic relations- that has resulted from this study consisted of 55 relations, out of which 42 have inverse relations.

1 Introduction

The lexicon of TKM prototype developed by Ou & Elsayed (2006) has been populated with lexical items extracted from the corpus developed to evaluate its major components. Efficient parsing of the corpus reflects the richness in linguistic model of TKM prototype but it was inept to map text on its ontology and to represent qualitative and quantitative information due to absence of a conceptual structure for the domain. The corpus contains text that conveys predicate and semantic relations among the elementary data units (Marcu et al, 2001). The predicate relations are useful to populate the lexicon but do not contribute to model the ontology. To model the ontology, we need to identify and categorize semantic relations. Semantic Relations, being qualitative and domain-specific, are important for modeling the ontology and can be formulated from a conceptual structure of the domain (Novak, 2004; Decker et al, 2000).

Being instructional, the text in the corpus sometimes conveys ambiguity to a knowledge mapping prototype if its knowledge model differs from human cognition. For example, a resistor is both a circuit component and a diagrammatic representation. To identify whether the role of a resistor is a component in physical connection or a component in diagram, the machine has to conceptualize the domain like human. A machine only identifies the appropriate roles of concepts in the domain if its knowledge model is developed with domain-specific semantic relations. Semantic relations for a large domain can be obtained by developing conceptual structure of the domain with concept maps as concept maps represent both textual and semantic relations graphically (Nathan & Kozminsky, 2004). Developing conceptual structure of the domain-specific corpus and developing a framework for semantic relations thus are challenges to accomplish.

In this paper, we present a procedure to develop conceptual structure for the domain DC electrical circuit by concept mapping a representative corpus (Mcenery et al, 2006). The corpus currently contains linguistic information like Part of Speech (POS) tags and Combinatory Categorical Grammar (CCG) tags (Clark et al, 2004), and stem of each word- which are useful for empirical linguistics (Lakoff, 1990). These functions enable the corpus aiding the linguist whereas the conceptual structure for the domain aids metacognition of the learners and educators (Fletcher-Flinn & Suddendorf, 1996). We also developed a framework for semantic relations from this conceptual structure which is important for both cognitive and functional linguistics (Gries & Stefanowitsch, 2006).

Anyone unfamiliar with a domain conceptualizes the domain in levels. Starting with reading domain-specific text, the person first conceptualizes the domain by relating the concepts in the text. This cognition is based on predicate relations among concepts. The person needs to relate the concepts with semantic relations if he wishes to extract knowledge represented in the text. This process completes when there remains no other concept except the context- the domain itself. Observing this process of human cognition for a specific domain, we developed the conceptual structure for the domain in levels. We manually conceptualized every sentence in the corpus and then represented them with CmapTools of IHMC (Cañas et al, 2004). These concept maps are at the base level (or level 0) and elicit 55 semantic relations and 42 inverse relations in the corpus. Using FACTOTUM Thesaurus (Chen et al, 2002; Micra, 2008) as a reference framework, we developed a framework to support these 97 domain-specific relations. Afterwards, we analyzed the concepts of the base level, grouped them and linked them with higher level relations to produce level 1 concept maps. This reduces the number of concepts and relations comparing to the base level. In a similar fashion, we developed level 2 concept maps as well. The domain DC electrical circuit is the only concept in context level (level 3). We stopped conceptualizing the domain at that point as we found the context of the domain as the only concept. These four levels of concept maps form the conceptual structure for the domain.

Section 2 depicts the procedure to develop the conceptual structure of the domain from the domain-specific corpus. The section also describes the development of the framework for semantic relations. Section 3 shows the four levels of concept maps for the corpus as well as the framework to support the semantic relations. In section 4, we conclude with a summary and indications for future work.

2 The Procedure

This section describes the development procedure of conceptual structure for the domain-specific corpus. We started conceptualizing the domain by taking a sample of the corpus. The concept maps of the sample provide thin predicate relations among concepts. We developed a framework to support predicate relations with a number of semantic relations- which will be used to develop the knowledge model of the TKM prototype.

2.1 Conceptual Structure for a Sample of the Corpus

The corpus contains 1,029 sentences collected from 144 web resources. Initially, we took 308 sentences from the corpus as sample which covers 30 percent of the corpus. We conceptualized each sentence from the sample manually. The outcome of the conceptualization led us to develop concepts and relations among them and graphically represented them with CmapTools. In most cases, the concepts are nouns and the relations are verbs.

To illustrate this procedure, for the sentence *One simple DC circuit consists of a voltage source (battery or voltaic cell) connected to a resistor*, we firstly conceptualized the sentence in the following manner:

1. DC circuit has voltage source as its component.
2. Battery and voltaic cell are voltage sources.
3. Battery and voltaic cell have similarity.
4. Voltage source can be connected to resistor.
5. DC circuit has resistor as its component.
6. As they all are satisfying the properties of a circuit, DC circuit is a type of circuit.

With this conceptualization of the sentence, we then graphically represented the concepts and the relations among them. The concept map for the sentence is depicted in Figure 1.

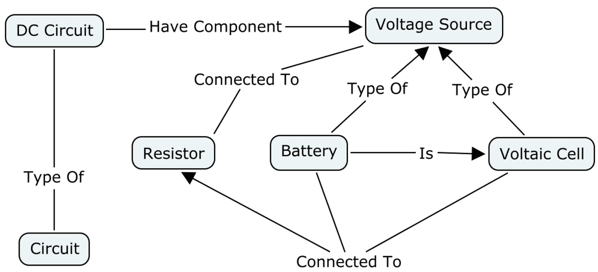

Figure 1. Concept map for a sentence from the corpus

As this concept map is developed by conceptualizing a sentence directly, we can say that this concept map is sitting at the base level. To develop higher level concept maps, we require to group concepts according to the semantics embedded in the sentence and to find relationships among these newly created groups. For this particular sentence, we defined groups named *circuit* and *circuit component*. We assigned *DC Circuit* and *Circuit* to the group *Circuit* and the rest of the concepts to the group *circuit component*. We can also find a relation between these two groups- circuit *is made of* circuit components. For a sentence *Resistors in the diagram are in parallel*- the concept *resistor* would be assigned to group of concepts called *Diagrammatic Notation* rather than *Circuit Components*. This process of grouping the concepts from the base level concept maps and finding relations among them produced four levels of concept maps for the sample of the corpus. The conceptual structure of the domain is comprised of all these concept maps resulted from human cognition at four different levels.

2.2 Framework for Semantic Relations

The relations that exist in the concept map depicted in Figure 1 are as follows:

1. DC Circuit *Have Component* Voltage source
2. Battery *Type Of* voltage source
3. Voltaic cell *Type Of* voltage source
4. Battery *Is* Voltaic Cell
5. Voltage Source *Connected To* Resistor
6. Battery *Connected To* Resistor
7. Voltaic Cell *Connected To* Resistor
8. DC Circuit *Have Component* Resistor
9. DC Circuit *Type of* Circuit

The relations are completely extracted from the linguistic information carried out by a sentence. They do no help out the user to conceptualize the domain using semantics- which is necessary to extract knowledge from the text. These relations are then analyzed to initiate developing the framework for the semantic relations in the text. The analysis provides us the following relations that are semantically embedded in the text-

1. Predicate Relation which describes parts that are physically related (e.g., Have Component)
2. Predicate Relation which describes hyponymy (e.g., Type Of), and synonymy (e.g., Is) that are similar
3. Predicate Relation which describes hierarchy or class (e.g., Type Of)
4. Predicate Relation which describes spatial relations (specifically location of objects) (e.g., Connected To)

Without creating the concept map from the original text, it is difficult to illustrate the semantic relations embedded in the text. The sentence in concern provides predicate relations that describe parts that are physically related, hyponymy, synonymy, hierarchy, and spatial relation. As the human does acquire and represent knowledge in this way, this process of conceptualization followed by mapping linguistic information on knowledge model also will allow the prototype mapping knowledge from the text onto the ontology efficiently. For example, the prototype now can provide the user knowledge like *voltage source* is a physical part of the *DC circuit*- which is not stated in the sentence but semantically it is present there.

We continue this procedure to reach a stage from where we can constitute a framework for semantic relations. As we continued developing concept maps with the CmapTools, the total number of concepts and relations increases but number of new concepts and relations decreases. We take two pages from the sample as a segment. After every segment, the number of concepts and relations are plotted. Figure 2 shows the cumulative increment of the number of concepts and relations. In sample six, we see a plateau showing that the number of concepts and relations are becoming stationary.

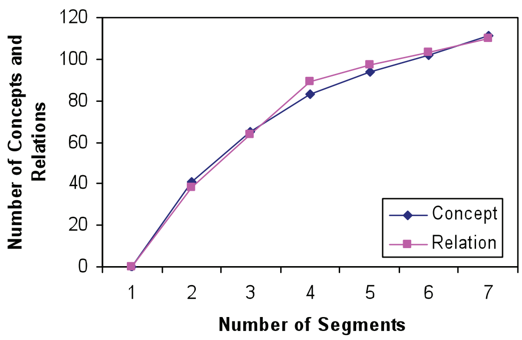

Figure 2. Graph to show that the number of concepts and relations in the corpus is becoming stationary

We also plotted number of new concepts and relations found in every segment (Figure 3). The plateau in Figure 3 shows that from sample six, the number of new concepts and relations are becoming stationary. These two observations led us to a decision that at this point (sample six) we can start developing the framework for semantic relations as the number of concepts and relations are not frequently fluctuating. The relations that we will come across by the concept maps after this point can be categorized according to the framework.

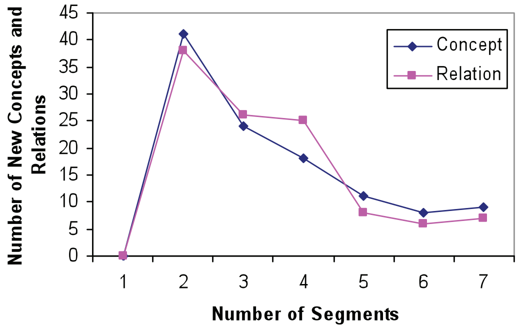

Figure 3. Graph to show that the number of new concepts and relations in the corpus is becoming stationary

At this stage, we came across 82 relations and 111 concepts in the sample. Relations in the sample may or may not have an inverse relation. For example, the relation *Have Type* can have inverse relation *Type Of*. In contrast, *Connected To* has no inverse relation. Analyzing all the relations, we found that they are predicate relations and relate the concepts without conveying the semantics. To derive the semantics conveyed by the relations relating the concepts, we developed the semantic relations in Tier 2 (Table 1) and fitted all the 82 predicate relations into the Tier 2 semantic relations.

2.3 Conceptual Structure for the Corpus

After having the relations and concepts from the sample of the corpus, we started developing the concept maps for the whole corpus using them. At stages, we came across new relations and they have been appropriately fitted into Tier 2 of the framework. When base level (level 0) concept maps for the corpus have been developed, there were 97 relations and 166 concepts and we had to adjust Tier 2 to support these relations.

Afterwards, we grouped level 0 concepts and relations to produce level 1 of concept maps. As we came across new predicate relations among concepts, we created Tier 1 to support the semantic relations in Tier 2. These two tiers of semantic relations comprise the domain-specific framework for semantic relations and can be supportive to all the predicate relations of the domain. In essence, the level 0 concept maps have the predicate relations and the semantics conveyed by them are supported by relations in Tier 2. Predicate relations in level 1 and level 2 concept maps are supported by Tier 1 semantic relations.

3 Results

Figure 4 shows the concept maps for the whole corpus. There are 12 groups of concepts holding 166 concepts present in the corpus. The concept maps also contain 55 semantic relations and 42 inverses. We call these concept maps- the base level (level 0) concept maps as they are directly developed from the text of the corpus.

From Figure 4, we see that the level 0 concept maps developed from the corpus is not human readable though this level assisted developing Tier 2 of the framework. Therefore, we further grouped level 0 concept maps to develop the level 1 maps shown in Figure 5. For educators and learners, this layer is more appropriate to conceptualize the domain. This level has the same 12 concepts as in Figure 4 but number of relations has been decreased to 11.

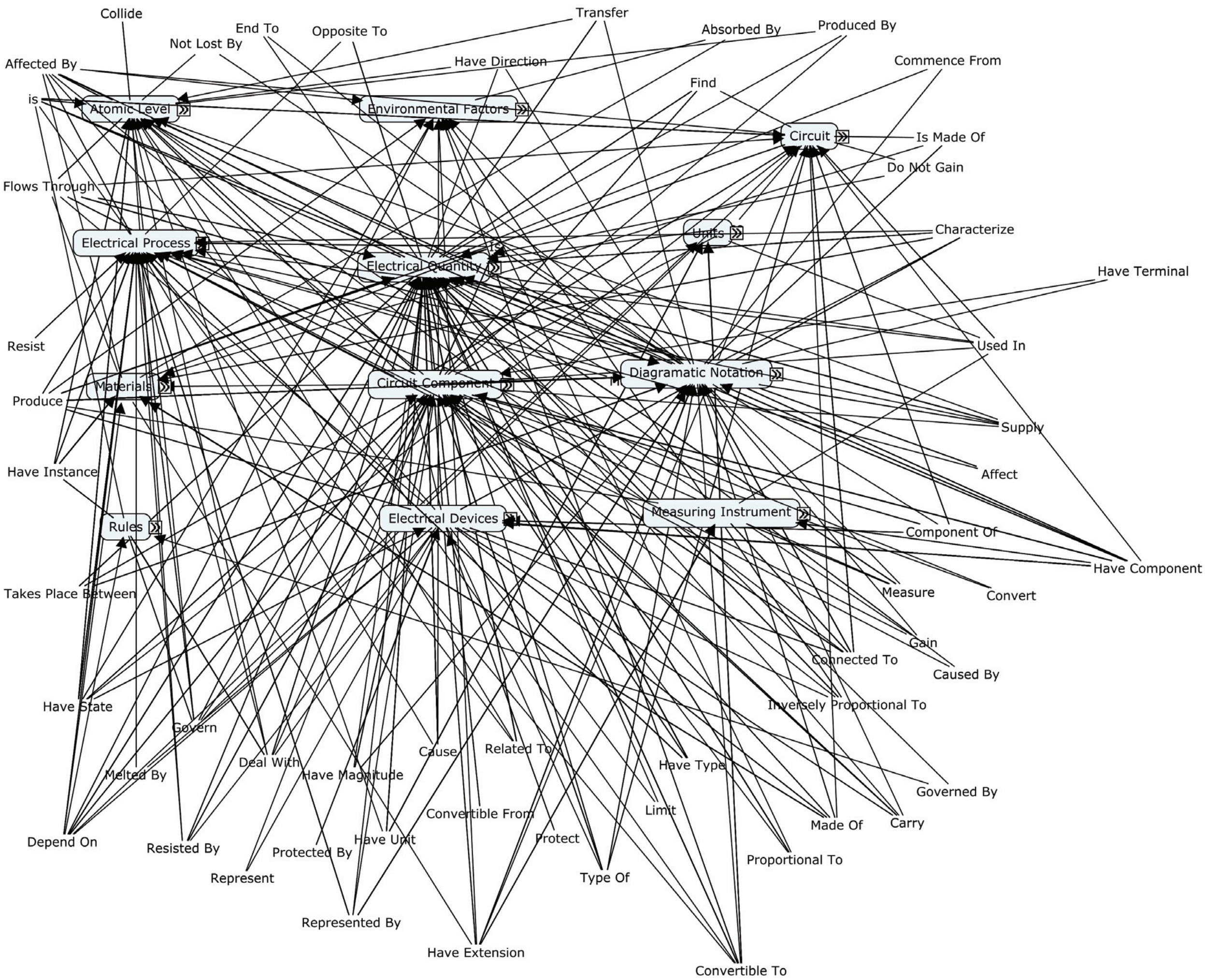

Figure 4. Concept maps developed for the corpus

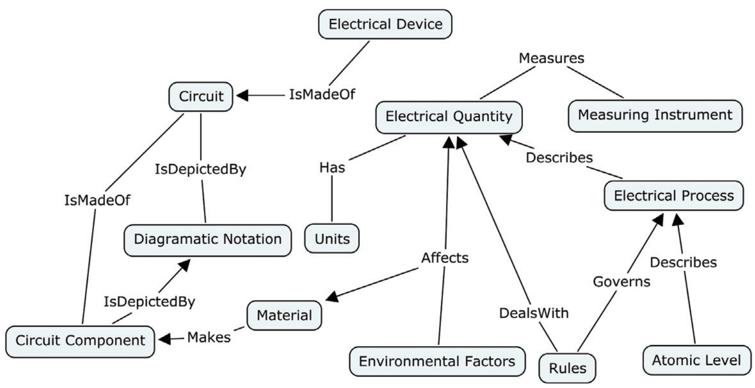

Figure 5. Level 1 concept maps for the corpus

Figure 6 shows the level 2 concept maps produced by combining concepts from the level 1 concept maps into groups. In this level, the number of concepts has decreased to six and number of relations has decreased to seven. The concept domain DC electrical circuit alone sits at the contextual level (Figure 7).

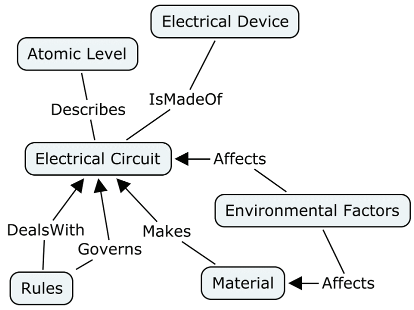

Figure 6. Level 2 concept maps for the corpus

Figure 7. Level 3 concept map for the corpus

Therefore, Figure 6 shows the highest level of conceptualization human can have on the domain. Figure 5 shows a more detailed view of the domain and Figure 4 leads the user to the deepest level of conceptualization for the domain. Together these four levels of concept maps form the conceptual structure of the domain.

The domain-specific framework for semantic relations is depicted in Table 1. The framework has three types of relations- predicate relations, instantiation and extension further categorized in three tiers- means the domain-specific corpus has these three semantic relations supported by other relations present in Tier 1 and Tier 2.

Semantic Relations	**Tier 1**	**Tier 2**
Predicate Relations	Hierarchy/ Class Inclusion	
	Physically Related	Parts
		Constituent Material
	Spatial Relations	Location of Objects
		Location of Activities
	Causally/ Functionally Related	Effect/ Partial Cause
		Production/ Generation
		Destruction
		Manifestation
		Conversion
	Instrumental Function/ Usage	Functions
		Use
	Human Role	
	Conceptually Related	Topic
		Representation
		Property
	Similarity	Synonymy
		Hyponymy
	Quantitative Relations	Numerical Relations
Instantiation		
Extension		

Table 1: Framework for semantic relations in the corpus

Discussion and Summary

We developed a conceptual structure for a domain-specific corpus using concept maps. When statistics for the presence of concepts and relations became consistent for a sample of the corpus, we developed Tier 2 of the framework for semantic relations to bridge between predicate and semantic relations among concepts. Then we developed conceptual structure for the whole corpus and discovered new relations among concepts. To support these relations, we developed Tier 1 of the framework. The framework is a generic and a categorical view of the relations existing in large amount of domain-specific text. As the framework is outcome of conceptualization of the domain, it facilitates the prototype for cognitive support and semantic retrieval. Total 97 relations are fit into Tier 2 and 1 that have 16 and nine categories of relations. We developed four levels of concept maps for the corpus that depicts the conceptual structure of the domain. The process of having levels in concept mapping helps cognitive linguistics to pick up the actual semantics embedded in different levels of human cognition. The similar procedure can be applied on any domain to develop a conceptual structure and a domain-specific framework to facilitate knowledge mapping.

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DIALOGIC CONCEPT MAPPING IN THE ZONE OF PROXIMAL DEVELOPMENT

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Abstract. Dialogic concept mapping uses a sociocognitive perspective for metacognition of the zone of proximal development in the present (cf. Valsiner & van der Veer, 1993). Cognitive theories of mental model (Johnson-Laird, 1983), concept mapping (Novak & Gowin, 1984), cognitive load (Sweller, 1994), and psychological distance (Sigel, 2002) are synthesized in dialogic concept mapping for operationalization in the sociocultural ZPD framework in the metacognition or "seeing" of ZPD instances. Case studies of student academic writers' dialogic concept maps are analyzed in this paper for the metacognition of ZPD instances. The results indicate there is a shifting collaboration in metacognitive ZPD-concept maps.

1 Introduction

Education is frequently divided between objectivism and subjectivism, or cognitive versus sociocultural learning theories. Traditionally, students had been taught from the cognitivist perspective that facts, like those presented in science and math, were the ruling principles in a pedagogy built upon Cartesian philosophy. Sociocultural theory (Vygotsky, 1978), however, emerged to posit the primacy of a social pedagogy mediated through tools, language, and culture. Our time is now an interesting mix of multimedia and multiculturalism mediating society through the Internet and culturally diverse viewpoints. Teaching-culture, in turn, is called upon to be open to the different perspectives and subjective ways of knowing that lie outside of traditional education. According to Giroux (1994),

> Indeterminacy rather than order should become the guiding principle of a pedagogy in which multiple views, possibilities, and differences are opened up as part of an attempt to read the future contingently rather than from the perspective of a master narrative that assumes rather than problematizes specific notions of work, progress, and agency. (¶20)

A step towards Giroux's indeterminacy or movement towards different ways of knowing can be taken through a *sociocognitive* perspective on learning. A sociocognitive perspective can counter-balance Cartesian beliefs of cognitivist objectivity with Vygotskian beliefs of cultural subjectivity. For example, the belief that cognitive and sociocultural perspectives of language learning are incommensurable or have incommensurabilities (e.g., Dunn & Lantolf, 1998) can be balanced with the belief that compatibilities exist between the perspectives and can lead to cross-fertilizations between the fields of learning (e.g., Sfard, 1998). These compatibilities can lead to cultivating understanding between the different metaphors of learning (acquisition and participation), instead of cultivating specious hegemonies over whose metaphor should be allowed to grow (e.g., Lantolf, 1996). A sociocognitive perspective on learning would mediate better understanding of the multiplicities of perceiving and knowing Giroux describes. Taking a sociocognitive perspective for epistemological insights into language learning and teaching help us to gain insights into mythified metaphors of learning such as the zone of proximal development (ZPD) (Vygotsky, 1978), which we might not otherwise see from hegemonic perspectives (see Lantolf, 1996, regarding mythification of metaphors).

The site of learning is an important case in point as it has been a major area of contention, creating hegemony between the sociocultural and cognitive fields. In sociocultural theories learning happens in the metaphorical site called the ZPD. Here, learning takes place in the relationship between the learner's "*actual developmental level*" and the learner's "*level of potential development,*" when her performance is scaffolded by a more able mediator or expert (Vygotsky, 1978, p. 86). Second language acquisition researchers, such as Donato (1994), Ohta (2001), and Swain (2000), have operationalized the construct to investigate how the interactions between novice and expert lead to learning in the ZPD, but the ZPD in sociocultural theories has not been an easy construct to define. Much has been written about the ZPD and there are definitions of not only what it is, but also by what it is not; how it cannot be defined except in retrospection; what it could be; what it should be; how to create it; how to scaffold learning within it; how to add to its effect; how it is being used; how it should not be used; and how it is realized. Whereas, in cognitive theories learning is what happens within an individual's mind. The current state of cognitive research idealizes learner metacognitive awareness of their learning. However, this poses a problem in sociocultural theory, since learning in the ZPD is defined in the prospective, but examined in the retrospective (Valsiner & van der Veer, 1993). Therefore, how can the learner examine her learning in the present tense? We often come up against this problem with our writing students who say, "How can I know what I mean until I see what I've said" (Bartholomae, 1982, p. 35). Through sociocognitive theories of learning it is possible to append to Valsiner and van der Veer's (1993) argument, and add that learner metacognition of her ZPD can be described in terms of the present using cognitive theories of: mental model (Johnson-Laird, 1983), concept mapping (Novak & Gowin, 1984; Greca & Moreira, 2000; Kinchin, 1998), cognitive load (Sweller, 1994), and psychological distance (Sigel, 2002) in the sociocultural ZPD framework. Specifically, student academic writers can know what they mean, when they *see* what they want to say, through shifting collaboration in the dialogic concept mapping of their ZPD.

The following sections describe the dialogic concept mapping process, and the shifting collaboration that can scaffold the metacognitive seeing of the ZPD. In section two, the theoretical framework of dialogic concept mapping is outlined. Section three is an overview of the research process with a short analysis of some of the factors influencing the participants' concept maps of their ZPD, that is, their ZPD-concept maps. Two ZPD-concept maps from case studies are analyzed: the first with ZPD-metacognition, and the second without ZPD-metacognition. Dialogic concept mapping is then summarized in section four.

2 Dialogic concept mapping framework

2.1 Visualization of the ZPD

Mental models represent our current understanding of a concept (Johnson-Laird, 1983). Consequently, they can represent our actual developmental level (ADL) through what we understand of a concept, and our potential developmental level (PDL) by what we could understand of a concept. We can externally represent mental models through concept maps (Novak & Gowin, 1984; Greca & Moreira, 2000; Kinchin & Hay, 2000): The cognition, categorization, and propositions of a mental model (Johnson-Laird, 1983) can be illustrated by the correlating *concepts*, *hierarchies*, and *relationships* in a concept map (Novak & Gowin, 1984). For example, my mental model of an ideal breed of dog for an apartment is the Pomeranian, because it is small, docile, and does not need a lot of space for exercise. Figure 1 is a concept map of this mental model:

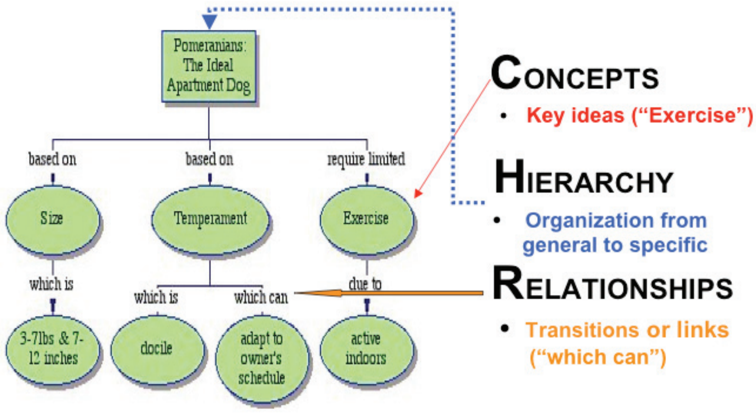

Figure 1. Concept map of my mental model of the ideal apartment dog.

Concept maps represent what we know and have yet to know by what is present or missing (i.e. *gaps*) in the map (Novak & Gowin, 1984). That is, what we know is our ADL, and what we have yet to know is our PDL. Thus, when the novice is scaffolded by an expert to see this gap in her concept map, then the concept map can represent her ZPD (see Kinchin, 1998, about concept map as ZPD). This is adduced from Vygotsky's (1978) definition of the ZPD, which is that the more capable peer or expert scaffolding the novice to reach her PDL from the ADL forms a ZPD.[1] These maps of the ZPD can be termed: *ZPD-concept map*s.

2.2 Metacognition of the ZPD

ZPD-concept maps allow the academic writer to *see* what she wants to say. However, the ZPD is a metaphorical zone defined in the prospective and examined from the retrospective (Vygotsky, 1978, pp. 86-87). And so, for the novice to also *know* what she means from seeing what she wants to say would require *metacognition* of her ZPD. But at the same time this seems impossible to have in the *present*: Valsiner and van der Veer (1993) say of the ZPD that "there is no way in which anybody can study that process directly, within the present" (p. 46). The ZPD is described as "that latter process—the constant forward move from what can be known in the present to what cannot yet (but might) become known in the next moment that has been difficult for psychologists to conceptualize” (Valsiner & van der Veer, 1993, p. 35, cited in Lantolf & Thorne, 2006, p. 266). But yet, conversely, cognitive tools like Sigel’s (2002) *psychological distancing* have helped us study the ZPD within the present (e.g., see the research published in Cocking & Renninger, eds., 1993), by viewing the ZPD through distance created within the mind.

Distance created within the mind is a “psychological space” (Sigel, 2002, p. 193) where we have room to take a metaphorical step back within the present to see the PDL and do problem-solving (i.e., learning). This psychological space is created through psychological distance, which consists of distance, discrepancy, and dialectics (Sigel & McGillicuddy-De Lisi, 2003): *Distance* is the (metaphorical) separation of self from the present (Sigel & McGillicuddy-De Lisi, 2003); *discrepancy* is the relationship between what is known and yet to be known (Cocking & Renninger, 1993); and *dialectics* is dialogue involving inquiry and reflection (Sigel & McGillicuddy-De Lisi, 2003). These three components work together to create psychological distance, which address Valsiner and van der Veer’s (1993) problem of retrospect, by making it possible to have a distanced perspective that allows the ZPD to be seen within the present. Therefore, student academic writers can “know” what they want to mean by “seeing” what they want to say for their writing, because a ZPD-concept map allows them to see their ZPD, while psychological distance allows them to study the ZPD within the present.

Consequently, this research uses a *dialogic concept mapping* process, which uses distance, discrepancy, and dialectics to create psychological distance to study the ZPD-concept map within the present. In dialogic concept mapping an expert concept map-maker (i.e., *mapper*) scaffolds a novice concept map-maker (i.e., *mappee*) to make a ZPD-concept map to be examined within the present via psychological distance.[2] This psychological distance in dialogic concept mapping can be created through:

1. Distance: (a) when the expert concept mapper draws the concept map (CM1) *for* the novice concept mappee; and also (b) when the mapper blocks the CM1 from the mappee’s view as it is being drawn.
2. Discrepancy: (a) from the mappee seeing the gaps from omissions/misconceptions in the CM1, (N.B., the CM1 gets redrawn into a new concept map [CM2] with the gaps of the CM1 now rectified in the CM2); and also (b) from the mappee seeing the differences between the CM1 and CM2.
3. Dialectics: (a) from the mappee relating the concepts for the CM1 (i.e., monologic discourse, Wells, 2007); (b) from the mappee being questioned by the mapper to clarify the propositions of the CM1 (i.e., dialogic discourse, Wells, 2007); (c) from the mappee seeing the gaps in her knowledge; (d) from the mappee explaining the changes made for the CM2 (monologic discourse); and (e) from the mappee discussing the differences between the CM1 and CM2 (dialogic discourse).

In this dialogic concept mapping process psychological distance is created for the mappee, so that she can study her ZPD-concept map within the present. The (metaphorical) distance lets the mappee study her ZPD; the discrepancy between her ADL knowledge and PDL knowledge helps her notice new knowledge; and the dialectics with the mapper helps the mappee to internalize this new knowledge. Learning is occurring for the mappee in the moving between internal and external knowledge via psychological distance, and integrating (or representing) the new knowledge within the mind (Cocking & Renninger, 1993).

2.3 Mediating tools: Translation, and shifting collaboration

Learning through dialogic concept mapping involves a high level of “element interactivity” or a high level of cognitive load (Sweller, 1994, p. 309), however. The learning, concept mapping, and metacognition required in dialogic concept mapping are each high element interactivity processes, but scaffolding in the forms of *translation* and *shifting collaboration* reduces element interactivity for the mappee, as well as promotes psychological distance. These mediating tools of translation and shifting collaboration are described in sections 2.3.1 and 2.3.2, as follows.

2.3.1 Translation of the concept map

In dialogic concept mapping, the mapper “translates” the mappee’s mental model information into knowledge and externally represents it through a concept map for the mappee.[3] The mapper reduces the element interactivity for the mappee by organizing the mappee’s concepts and their hierarchy and relationships into a concept map, which the mapper draws *for* the mappee. Being the mappee’s “translator” in this manner helps to reduce the mappee’s cognitive load to free up the mappee’s mental processes, so she can “know” what she means (in her writing). That is, the mappee is scaffolded to enable her to better focus on metacognition of her ZPD-concept map, in the present.

2.3.2 Shifting collaboration

During the translation, the dialogue between the mapper and mappee is *monologic* and *dialogic*. According to Wells (2007), the monologic mode of communication is associated with authority and expert knowledge types of discourse, and does not require a rejoinder. Whereas, the dialogic mode of discourse (like Giroux's non-master narratives): allows for multiple valid perspectives; is collaborative; and makes knowledge-building possible by eliciting questioning and thinking in the discourse (Wells, 2007, p. 256). Having both types of discourse creates the psychological distance needed to learn in the dialogic concept mapping process: "This discrepancy between two perspectives for interpreting the world is termed *psychological distance*" (Cocking & Renninger, 1993, p. 5).

Through collaborative dialogue (Swain, 2000)[4] to create the ZPD-concept map in the dialogic concept mapping process, the expert and novice roles shift via: collective scaffolding (Donato, 1994)[5] and a type of pooled expertise (Ohta, 2001).[6] The shifting between the monologic and dialogic modes also allows for the roles of expert (i.e., associated with authoritative-discourse) and novice (i.e., associated with learning-discourse) to shift between the mapper and mappee. This shifting of expert and novice roles is termed here as *shifting collaboration*. Shifting collaboration can also occur when the mapper is novice in the knowledge-building (i.e., learning) about the mappee's mental model and then shifts to mapper as the expert in concept map-making of the mappee's mental model. Correspondingly, the mappee shifts from the novice in concept map-making of her mental model, and also to the expert in the knowledge-building of her mental model. To restate this, the mapper is expert of making concept maps and the mappee is the expert of her ADL. Though, even when there are situations where both are in the novice roles, collective scaffolding (and pooled expertise) makes it possible for the dyad to help each other to learn despite there sometimes being incomplete knowledge from incomplete, even erroneous, mental models of a concept.

3 Dialogic concept mapping process

The materials used in dialogic concept mapping are blank paper, black and red ink pens, and a clipboard to use as a temporary divider to initially block the CM1 from the mappee's view. The ten iterative steps for dialogic concept mapping are: (a) mapper asks mappee open-ended questions to elicit key points about mappee's writing topic (dialogic mode); (b) mappee relates her mental model (monologic mode); (c) mapper confirms information by restating to mappee (monologic mode); (d) mappee agrees, or corrects mapper's mental model (dialogic mode); (e) mapper draws[7] (hidden) CM1 in black ink; (f) mapper reveals CM1; (g) mapper and mappee dialogue on any conflicts within CM1 (dialogic mode); (h) mapper and mappee collaborate and mapper draws (unhidden) CM2 in red ink; (i) possible, further conflicts (i.e. gaps) result in further changes to CM2 (steps [c], [d], [h], and [i] can be repeated); and (j) mapper questions mappee about the visible ZPDs to scaffold changes between mappee's CM1 to CM2, and in result, the mappee can exhibit her *metacognition* of the ZPD(s), which makes the CM2 a metacognitive ZPD-concept map (for sample questions, see Kim, 2008).

3.1 ZPD-concept maps

As a part of my research for a metacognitive writing process, I had student academic writers participate in dialogic concept mapping sessions as a way for them to know what they mean by seeing what they want to say for their writing assignments. In the cases of Zara and Fiona (pseudonyms), they were both writing a Master's thesis. The sessions resulted in a series of their concept maps, and the following are examples of: Zara's ADL, and ZPD-concept map with shifting collaboration; and Fiona's static ZPD-concept map (see Kim, 2008, for complete data).

Zara's mental model of her writing topic on second language acquisition in foreign contexts is translated into her CM1 below (Figure 2), and visually represents her ADL on this topic:

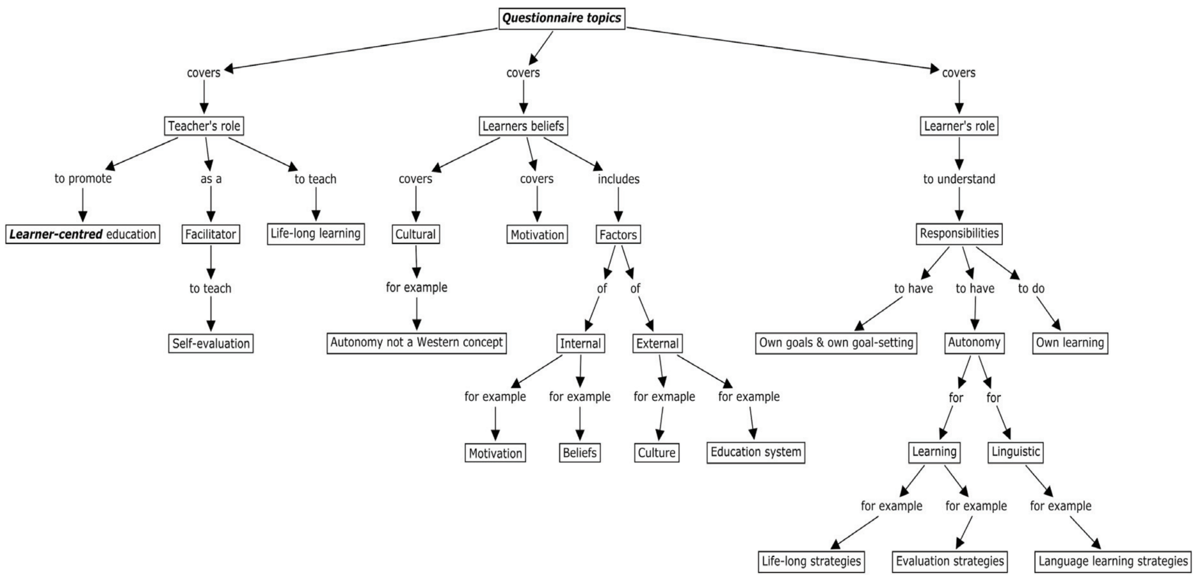

Figure 2. Translation of mental model to ADL: Zara's CM1.

She saw discrepancies within this CM1 (Figure 2) of what *was* understood about her thesis by the mapper versus what she *wanted* understood about her thesis as the mappee, and thus a subsequent ZPD-concept map (Figure 3) was created dialectically between mappee and mapper to represent the PDLs. For example, Zara changes her general topic of *Questionnaire topics* (which is positioned as the first, over-arching concept in her CM1, in Figure 2) to *Learner autonomy* (Figure 3). She also sees better, through the collaboration, what she wants to say and adds 15 new concepts. These changes are highlighted with the new concepts in oval:

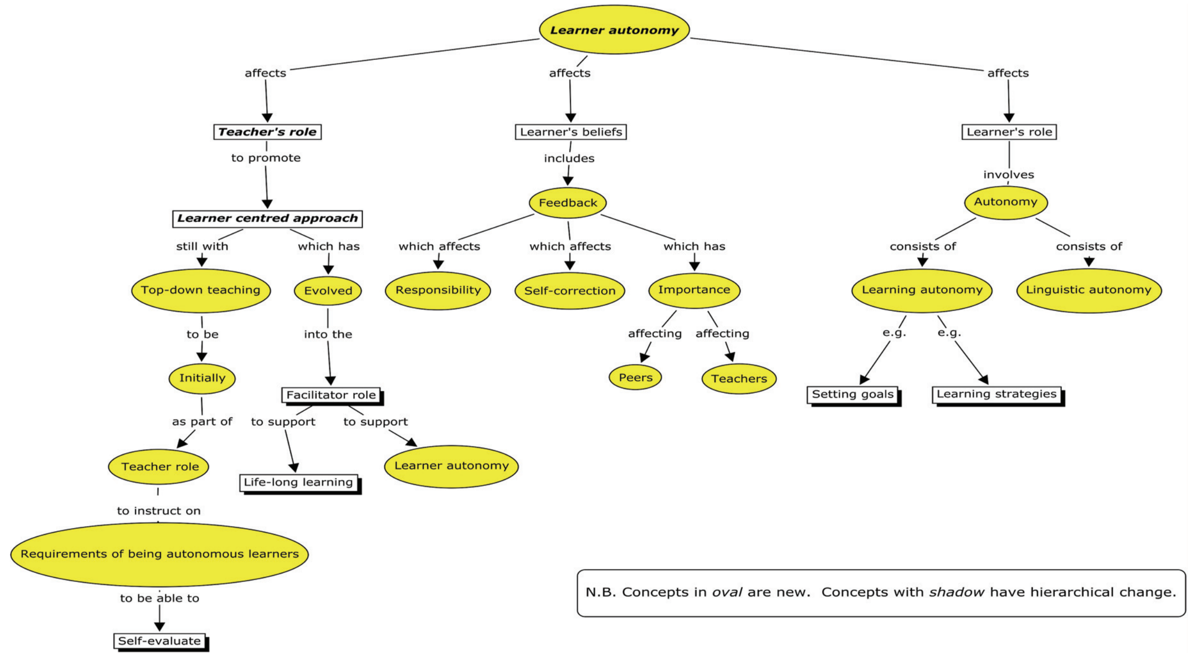

Figure 3. Zara's metacognitive ZPD-concept map.

Most notably with Zara's ZPD-concept map, she "sees" that *learner centred approach* is an important concept in the *teacher's role* to promote her main topic: *Learner autonomy*, and she collapses other concepts to be subsumed by the learner centred approach concept. During the session, I asked Zara why she made the change and she explained that the map helps her to literally *see* the direction she needs to go in. This noticing within the present through psychological distance appears to have scaffolded a *metacognitive* ZPD-concept map.

Zara's concept mapping session was collaborative, and the monologic and dialogic modes shifted between mappee and mapper. At times the mappee was expert scaffolding the mapper to understand, and other times the mapper was the expert scaffolding the mappee about what was being understood. The dynamic changes in Zara's several concept maps during the session reflected the movement between monologic and dialogic discourse and created a shifting collaboration of expertise, which created discrepancies in knowledge and scaffolded Zara's metacognitive ZPD-concept map or study of her ZPD within the present.

3.2 Static ZPD-concept map

Similar to Zara, Fiona is writing about language learning, but on the topic of background French language experience: *French Immersion Experiences* versus *Francophone Influence*, as factors in French language ability. The left-hand side concept map in Figure 4 is Fiona's CM2, and it is not in the typical hierarchical form of more general concepts positioned higher up and subsuming more specific concepts such as examples, which are positioned hierarchically lower in concept maps. Therefore, the *Mapper's version* (right-hand side concept map) in Figure 4 was suggested to the mappee as a PDL, since it would scaffold the (linear) academic writing format of a Master's thesis. However, the mappee was adamant against any further changes (i.e., further PDLs) being possible with her CM2 at the time and rejected the Mapper's version.

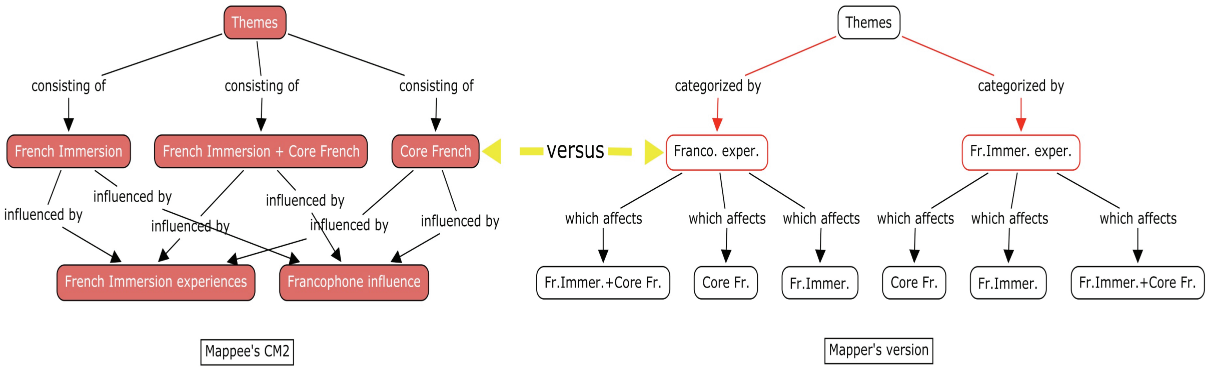

Figure 4. Mappee's CM2 versus mapper's CM2.

This session had a ZPD-concept map, in the form of the *Mappee's CM2* (left-hand side concept map; Figure 4). However, Fiona maintained an unmoving monologic stance: she engaged in monologic discourse without shifting into dialogic discourse, and the expert role did not dynamically shift in the dyad. Due to this the mapper was not allowed to shift into the expert role and scaffold the mappee to "notice" or acknowledge discrepancies with the mappee's CM2. Psychological distance (i.e., distance, discrepancy, and dialectics) to scaffold a metacognitive ZPD-concept map was not created, because the dialectics of questioning the mappee on potential discrepancies were absent. So, shifting collaboration, and thus collective scaffolding and pooled expertise (e.g., Donato, 1994; Ohta, 2001), in order to scaffold knowledge building was limited, which meant collaborative dialogue to negotiate discrepancies (Cocking & Renninger, 1999) or metacognitive knowledge building (Swain, 2000) was absent.

Distance was created in the mappee's concept mapping session through the mapper's act of translating the mappee's mental model into a concept map of her ADL. However, the dialectics and discrepancies that are part of psychological distance and scaffold the seeing of PDLs for ZPD-metacognition within the present were absent from this session. Fiona's CM2 was of a ZPD that was static for that concept mapping session and represented the "unshifting" expert-novice roles during the session. Collective scaffolding or pooled expertise was absent, though a *static* ZPD-concept map was present.

4 Conclusion

Dialogic concept mapping makes it possible for instances of the ZPD to be examined within the present, which appends to Valsiner and van der Veer's (1993) argument that the prospective ZPD is only examinable in the retrospective. These ZPD instances are visually represented through concept maps created through dialogue and collaboration in the ZPD (cf. Ohta, 2001; Donato, 1994; Swain, 2000) via shifting expert-novice roles. Shifting collaboration occurs between an expert, the "mapper", and a novice, the "mappee". The mappee relates her mental model of a concept through dialogue with the mapper, and the mapper "translates" the mental model into a concept map of the mappee's ADL. Translating for the mappee creates psychological distance for the mappee by distancing her from her map to create a metaphorical space (Sigel, 2002) and scaffold a metacognition of her ZPD in the present, which typically occurs through the distance created in retrospect. Translating for the mappee can also reduce cognitive load, that is, free up the mappee's mental processes for the metacognition of any PDL(s) in her concept map.

The mappee's concept map visually represents the ZPD (Kinchin, 1998), and in this research the mappee's mental model is directly correlated to the ADL, and "gaps" in her concept map reflect a PDL. Therefore, from Vygotsky's (1978) definition of the ZPD as forming from the more capable or expert scaffolding the novice to reach her PDL from the ADL, moments or instances of the mappee's ZPD are examinable, because the mappee's concept map represents her ZPD when both the ADL and PDL are present. When the mappee "sees" that there is something missing, or that she knows what she means from seeing what she wants to say, a metacognitive ZPD-concept map can be created.

Analysis of these instances reveals a shifting collaboration as roles of expert and novice shift within the mapper-mapping dyad. For example, this occurs when the mapper is novice in meaning-making or learning about the mappee's mental model, and then the mapper is expert in map-making of the mappee's mental model. In corollary, the mappee is novice in map-making of her mental model, and then the mappee is expert in meaning-making of her mental model. In the translation of mental model into a concept map, the mapper is expert of making concept maps and the mappee is the expert of her ADL, and the roles of who is the expert-scaffolding-the-novice shift as both collaborate in the dyad to create a ZPD-concept map.

The dialogic concept mapping process is used in my case studies of academic writing students' ZPD-concept maps, as part of my research on scaffolding a metacognitive-zone writing process. Dialogic concept mapping, in addition to representing mental models, focuses on creating psychological distance and reducing the cognitive load for the mappee, through the collaborative translation of the mappee's mental model into a concept map of her ADL. The sociocognitive compatibilities between psychological distance and the ZPD are used to foster cross-fertilization between the acquisition and participation fields of learning (Sfard, 1998). Cognitive theories of: mental models, concept mapping, cognitive load, and psychological distance are synthesized for operationalization in the sociocultural ZPD framework to scaffold metacognition of the ZPD in the present, instead of metacognition of the ZPD in the retrospective.

Notes

[1] Artemeva defines the ZPD as: "ZPD is the PDL minus the ADL," (N. Artemeva, personal communication, March 26, 2007).

[2] *Mappee* and *mapper* terminology suggested by D. Woods, personal communication, March 26, 2007.

[3] Grove-Ditlevsen (2007) discusses these maps made by language translators as the transforming of information into knowledge, or mapping information into knowledge.

[4] Swain (2000) describes how *collaborative dialogue* occurs when learners participate in metacognitive "knowledge-building dialogue" (p. 97); they discuss and negotiate to problem-solve, and create new knowledge by reflecting on what they say. Metacognitive learner-dialogue is significant, because it allows for the creation of new knowledge for the learners.

[5] Donato (1994) observes that *collective scaffolding* allows novices to scaffold each other to derive correct knowledge from "incomplete and incorrect knowledge" (p. 45). Although, the learners may be "individually novices," they each possess knowledge that make them "collectively experts" and able to collaboratively scaffold each other (Donato, 1994, p. 46).

[6] Ohta (2001, p. 76) builds upon collective scaffolding, and explains how learning in peer interactions is possible, because of *pooled expertise*. No one peer is necessarily the expert in the scaffolding; the peers are able to scaffold each other when their cognitive processes (Ohta refers to working memory) are freed up. Three factors during peer dialogic interactions work together to allow (non-expert) peer learners to scaffold each other: (a) possessed knowledge, (b) capacity to apply their knowledge, and (c) ability to project or predict in interlocutions. The combination of these factors allows learner's working memory to focus on and be able to scaffold other learners, despite being novices themselves.

[7] The concept maps are drawn by hand during the concept mapping sessions, but were converted afterward with CmapTools software for post-session analyses.

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DIGITAL CONCEPT MAPS AS POWERFUL INTERFACES FOR ENHANCING INFORMATION SEARCH. AN EXPERIMENTAL STUDY ON THE EFFECTS OF SEMANTIC CUEING

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Abstract. Research on the effectiveness of concept maps used as interfaces for knowledge-based information search has yielded inconsistent results. Simply representing content structures in a visual-spatial format has not resulted in higher performance or more positive usability ratings as compared to traditional interfaces. The assumption behind the study presented here is that the potential for semantic cueing of task-relevant information has not yet been fully exploited. An experiment was performed to study the effects of semantic cueing. Two types of interfaces, a digital concept map and a digital concept list, were compared. In the concept map condition, visual-spatial highlighting of category relations, as well as verbally labelled links for cueing semantic relations, were used for cueing correct decisions on the task-relevance of information resources. In the concept list condition only visual-spatial highlighting was used. The results showed that users of both interfaces showed no significant differences when resources had to be localized on the basis of category relationships. However, significant differences showed up when semantic (functional) relationships had to be taken into consideration. The results corresponded well with the usability ratings by the subjects. The overall conclusion is that digital concept maps may serve as powerful interfaces for enhancing information search if their inherent potential for semantic cueing of relevant resources is exploited in a task-appropriate manner.

1 Conceptual background

People seeking information need to make sense of the information and find what is relevant for a particular task. Thus it seems that the most effective communication not only provides the resources of task-appropriate information, but also the semantic relations between relevant topics of the resources. Orientation and navigation devices, for example hierarchical topic lists, site maps, structured lists of URLs, and concept maps, have been suggested as interfaces to help users make sense of a content domain and to provide users access to digital information resources (Rouet, Potelle, & Goumi, 2005). Whereas all these interfaces may reduce cognitive load by providing a structure that helps users decide upon the task-relevance of a particular resource, there are some typical features that seem to render some of the devices more effective in fostering information search than others.

A central aspect is semantic cueing. Hierarchical topic lists, site maps, and structured lists of URLs provide basic, implicit semantic cues concerning the hierarchical structure of the represented content domain. Outlining the hierarchical structure of a content domain in a visual-spatial format may help users to orient themselves. They can then navigate and infer super-ordinate and sub-ordinate relationships between topics (concepts), like category relations (is part of), and concept-example relations (is an example of). This is advantageous for making sense of the structure of the overall domain. A visual-spatial outline may also help users acquire knowledge and form a coherent mental representation of the knowledge domain (Kintsch & van Dijk, 1978). However, although many content structures may be represented adequately by using hierarchical outlines, a hybrid format using both hierarchical and web-like structures may be more appropriate for representing the interrelatedness of concepts in complex knowledge structures.

Concept maps have been suggested as an appropriate tool for representing knowledge structures (Novak & Gowin, 1984**;** Tergan, 2005; Novak & Cañas, 2006). A concept map according to Novak & Gowin is a visual-spatial array that represents elements of knowledge by means of nodes and directed labelled links. The nodes in a concept map represent ideas, concepts and beliefs, and the links show the relations among the concepts. Although concept maps are considered to be a hierarchical representation tool, a network structure for representing semantic interrelations can easily be implemented by using cross-links.

Since the implementation of digital concept mapping tools (e.g. Inspiration™, http://www.inspiration.com/; CmapTools™, http://cmap.ihmc.us/; SMART Ideas™, http://www2.smarttech.com/st/en-US/Products/SMART+Ideas/), concept maps have not only been used for the representation of conceptual knowledge but also for a comprehensive representation of content knowledge and resource knowledge (Tergan, 2005). They are used for representing and communicating information and information resources, and, used as an interface, for fostering orientation, navigation, and information access (e.g. Hoffman, Cañas, & Ford, 2000; Coffey & Cañas, 2006). Used as interfaces, concept maps are appreciated for their explicitness in representing the semantics of a domain, for offering visual search, and for providing a knowledge-based visual access to information resources. Semantic cues indicating the relevance of an information resource can appear in several explicit forms. They may be the labels of concepts, aspects of the graphical representation itself, like the distance between represented resources indicating a thematic or contextual relationship between contents. Semantic cues might also be the explicit labelling of the kind of relationships between contents. It has been suggested that concept maps support external cognition, since their semantic explicitness facilitates inferences and decisions about the relevance of represented knowledge elements for coping with a particular task (Scaife & Rogers, 1996; Tergan, 2005). Because concept maps may represent the meaning inherent in information visualization, they could provide a bridging technology that might integrate aspects of knowledge and information visualization approaches (Keller & Tergan, 2005).

As an interface to information resources, digital concept maps may function as a vehicle to communicate the semantic interrelation between topics of resources of a digital content domain. In this way, they could foster information search processes better than other structural orientation, navigation, and information access tools. Basic assumptions underlying the use of concept maps as interfaces are: (1) Because concept maps are explicit and problem-centred in representing semantic relations between concepts of a domain, they may be more effective as an interface with respect to information search efficacy than other tools. The explicit labelling of relations between concepts may provide information seekers an advantage in searching for hyperlinked information resources and in deciding on whether the resources may contain information relevant for coping with a particular task. A semantic understanding of the task-relevance of content topics and related information resources enhances information search. (2) Because of the visual-spatial layout of the concepts, the topic structure of a knowledge domain can be represented more clearly with concept maps. Thus concept maps may be evaluated by information seekers more positively than other interfaces with respect to perceived cognitive load.

This paper presents an experimental study that intends to cross-validate the results of a previous study of Goumi, Rouet, & Aubert (2003) which seems to contradict any advantages of concept maps. It further intends to shed more light on the reasons why and the conditions when concept maps as interfaces may foster information search.

2 Research background

Research on the effectiveness of concept maps used as interfaces for information search has yielded inconsistent results (Carnot, Dunn, Cañas, Gram, & Muldoon, 2001; Weideman & Kritzinger, 2003; Goumi, Rouet, & Aubert, 2003; see Rouet, Potelle, & Goumi, 2005 for a recent review of research on the role of content representations in search tasks). Carnot et al. and Weideman & Kritzinger found that a hierarchical concept map used as interface proved to be more effective in search performance, easier to handle and more popular than a Web page-based interface. It could be suggested that in these studies, concept maps were more effective because the content structure of the hypertext was highlighted in a visual-spatial representation. Thus, when node labels and visual-spatial semantic cues were used in a concept map interface, Web pages could be searched visually on the basis of knowledge about the inherent content structure. In contrast, in the Web page-based interface the structure remained implicit and could not be used for deciding about the relevance of a Web page.

Goumi et al. (2003) compared a concept map interface with an alphabetic index and a hybrid interface, composed of an alphabetic index and a hierarchical content list. In this comparison, they found no advantages of the concept map interface. The concept map used in their study had two layers of representations. The top level layer consisted of an interwoven puzzle-like assembly of concept nodes. The second level layer was a web-like node-link map with non-labelled associative non-directed links. In the study of Goumi et al. students had to search for articles in a CD-ROM multimedia database on "Electronics", containing about 90 articles. They then had to answer questions by using more detailed information contained in the articles. The number of clicks to find a task-relevant article by using the allocated interface was assessed. It turned out that for less knowledgeable students the alphabetic index was the most effective interface. Advanced students performed more effectively with the hybrid interface. They profited most by using the hierarchical content list of this interface to pre-select relevant areas of knowledge. The hybrid interface required fewer clicks than the two other interfaces, even though the difference between the "hybrid" and "index" interface was not significant. All in all, the concept map interface was evaluated by searchers as less suitable, and less popular.

In order to make sense of the results of Goumi et al. it is helpful to analyse the conditions of the study, particularly the task situation. The task was to answer topic related questions by using information contained in an article. However, the concept map used in this study does not seem to be appropriate for fostering information search. In the first place, the format of the map is not inherently hierarchical, which is normally a typical feature of most concept maps (Novak & Cañas, 2006). In the second place, semantic relations between nodes are not verbally labelled. In order to select a resource and study the respective article to answer a question, the participant could only consider the meaning of the labels used for indicating content topics. A more detailed consideration of links that represented the topic structure of the domain was not possible and not intended by the authors.

There may be other reasons why the concept map condition did not show benefit: The concept map used by Goumi et al. had two layers of representation, and each was presented in a different window at the screen. Clicking on a label at the top level representation opened up the second level. An article could only be accessed at the second level of representation. It has been shown that too complex, less structured, and layered concept maps were too difficult to handle for many users (Wiegmann, Dansereau, McCagg, Rewey, & Pitre, 1992). It may be assumed that the concept map's lack of clarity and usability was detrimental to effective use in the search process. Because of these impediments, it is not surprising that the results showed no advantage in information search for subjects in the concept map condition. If the map had been more clearly arranged so that the students could capitalize on the potential of its use, the students' evaluation of the suitability of concept maps might have been more positive.

In the Goumi et al. (2003) experiment it seems to have been easier for information seekers to infer the task-relevance of the corresponding articles from the label of a node representing a content domain. The prominent feature of concept maps of using directed and labelled links to semantically cue the relevance of a topic was not capitalized on. It may be concluded that the map used in the experiment lacked central features for fostering information search and was suboptimal for many users to cope effectively with the experimental tasks. Therefore, no benefit was shown as compared to the alphabetical index and the hybrid interface conditions. Empirical data as well as theoretical reflections support the assumption that a concept map will only be effective as an interface for fostering information search if it is directly relevant to the task, if it is clearly designed, and if it can be handled easily without imposing additional cognitive load to the users. In order to study the potential and advantages of a concept map as an interface, care has to be taken to fulfil these conditions. To elaborate on these three essential conditions: (1) Concept maps' potential for fostering information search can only be realized if their prominent feature, namely labelled and directed semantic links for semantically cueing the relevance of content topics, is capitalized upon in the design of the map so that users can decide if the topics match the demands of the task. (2) Concept maps as compared to other interfaces can only be more effective if users recognize an additional value in considering labelled and directed semantic links when searching for information resources. Otherwise alphabetic or hierarchically structured representations will do. (3) Concept maps must not impose additional cognitive load on users. They must be clearly designed. A manageable number of nodes and a clear structuring of the nodes are essential.

The basic assumption is: Concept maps will only fulfil their potential as an interface if the search conditions match the conditions for optimal use. If a concept map fulfils these conditions it will be an inherently more effective interface for supporting decisions about the task-relevance of content topics and related information resources. It will also be more effective than a simply alphabetic and hierarchical tool that leaves the semantic relations between content topics implicit, so that the users themselves have to infer any relation of information resources from studying the corresponding contents.

3 Experimental approach

An experiment was performed to analyse the effects of two types of interfaces: a concept map interface, and a concept list interface. These two interfaces differed in the explicitness of semantic cueing of category and functional relations indicating the task-relevance of information resources: We used the following dependent variables:

- Search time (time needed for deciding on the task-appropriateness of a resource)
- Correctness of a decision
- Estimated cognitive load (as measured with a 7 point-rating scale on the mental effort needed for coping with a task)

Four central hypotheses were tested:

1. If a task requires the consideration of category relations between concepts, search time and correctness of decisions of information seekers using a concept map interface or a concept list interface will not differ. In both interfaces the category relations can be inferred from the existing visual-spatial cues by using hierarchical structuring of concepts.

2. If a task requires the consideration of functional relations between concepts, the search performance of information seekers using a concept map interface as compared to a concept list interface will differ significantly: Using a concept map will be significantly more effective in reducing search time and fostering correct decisions about the task-relevance of an information resource under conditions of considering one, two or three and more relations.
3. The perceived cognitive load among subjects using the concept map and the concept list will differ depending on the type of relation and the number of functional relations which have to be considered in order to decide about the task-relevance of an information resource. If only category relations have to be considered, the evaluation of the perceived cognitive load of the concept map will not differ significantly from the evaluation of the concept list.
4. If a task requires the consideration of one, two, or three and more functional relations, the perceived cognitive load will differ significantly among subjects using the two different interfaces. Subjects working with the concept map will evaluate the perceived cognitive load as lower compared to subjects working with the concept list interface, under conditions of considering one, two or three and more relations.

3.1 Method

3.1.1 Subjects

Subjects of the study were 44 paid students (31 female, 13 male) at the University of Tuebingen, Germany. The average age was 23,59 (*SD* = 4,04). The students were randomly assigned to the experimental condition or to the control condition.

3.1.2 Materials

A pre-selected set of 34 Web pages of the internet portal e-teaching.org (www.e-teaching.org) was used. The portal consists of about 2000 Web pages on E-Teaching. The selection of Web pages covered the topic "Technologies of Web-based Communication in Online Teaching Scenarios". The labels of the Web pages were represented as concepts. The concepts were hyperlinked to corresponding Web pages. Both a concept map (Fig. 1) and a concept list (Fig. 2) were generated. Both interfaces equally represent content structures visual-spatially by means of hierarchical structuring. However, they differ in the explicitness of semantic cueing of task-relevant information resources. Two types of semantic relations were used: category relations (e.g. "is an example of") for representing content structures; and functional relations (e.g. "is used by") for representing task-relevant relations among topics of the knowledge domain, displayed as concept nodes. Both types of relations were represented implicitly in the concept list interface but explicitly in the concept map interface. The explicit representation in the concept map interface was carried out by means of explicit verbal labelling of the links between content topics and related information resources. Category relations in both interfaces were represented visual-spatially. In the concept map interface all relations were also labelled verbally. Functional relations in the concept list condition were not represented visual-spatially. They had to be inferred by first selecting a task-relevant Web site and then extracting the relation from the content. For reasons of search economy the task-relevant contents of an information resource were highlighted by using red coloured characters.

3.1.3 Task

The task was to answer questions that required decisions concerning the relevance of information resources. Each of the questions induced the information seeker to consider relations between represented topics, as a prerequisite for deciding about the relevance of an information resource linked to a particular topic. Several types of questions had to be answered. The questions were multiple choice questions with a varying number of alternatives, of which up to three could be correct. Answering the questions required the participant to consider whether there was either a category relation between topics (concepts) of Web pages, or whether there were one or more functional relations between topics. The primary task was to try to answer the questions on the basis of the concept map and concept list interface respectively. However, subjects were Also free to seek information in the contents of task-relevant resources.

Examples

Example of a task requiring consideration of 1 category relationship
You want to find more detailed information about Learning Management Systems. You are looking for one or more resources which may contain more detailed information. Which of the following resources of the internet-portal e-teaching.org may be of relevance? (1) Bubble Sort, (2) E-Chalk, (3) ILIAS, (4) CLIX.

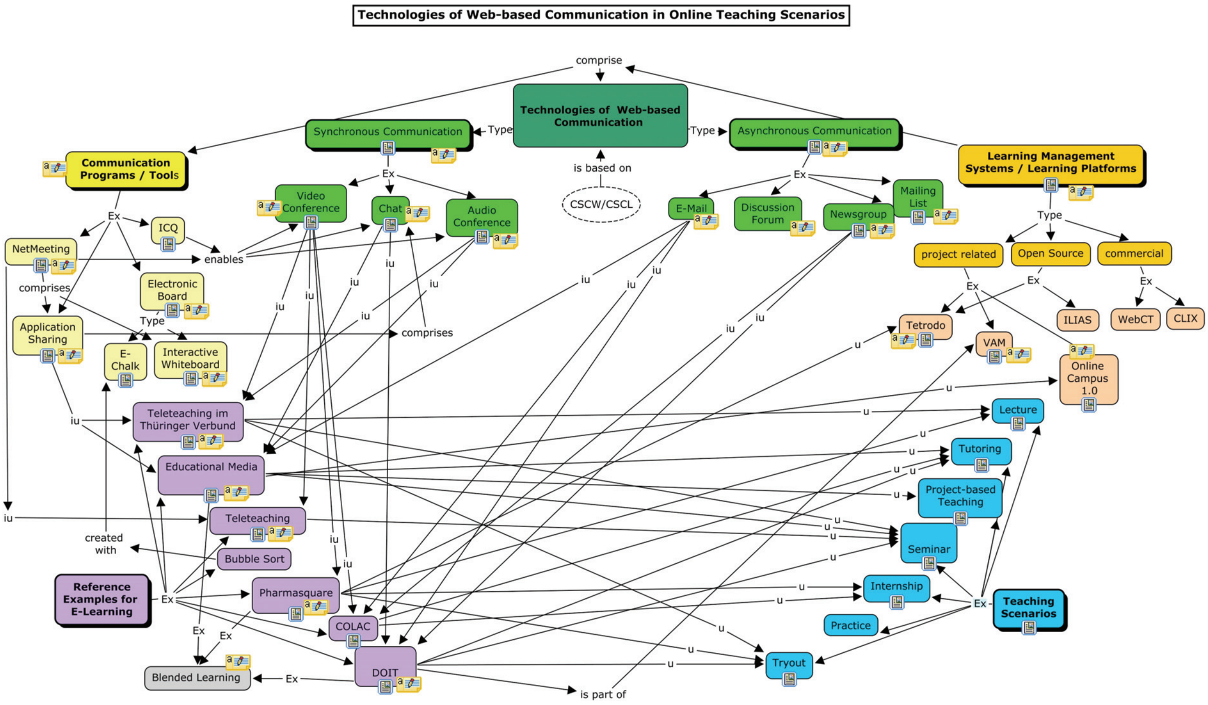

Figure 1: Concept map interface with a hybrid representation of concepts and labelled and directed semantic relations. Concepts belonging to the same category are represented visual-spatially, same-colour and structured hierarchically. Abbreviations of labels for relations are used for assuring clarity (Ex: example; iu: is used; u: uses).

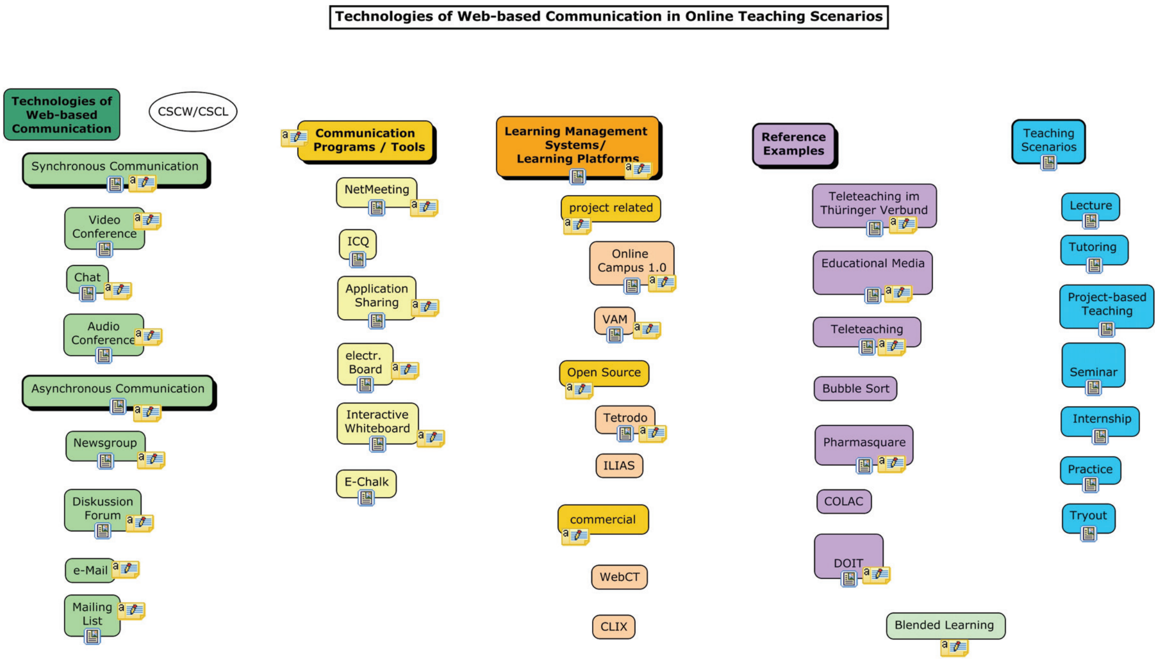

Figure 2: Concept list interface with a hierarchical representation of concepts. Concepts belonging to the same category are represented visual-spatially, same-colour and structured hierarchically.

Example of a task requiring consideration of 1 functional relationship

You are searching for e-learning reference systems to find more detailed information about the online use of teaching methods. Please decide on which of the teaching methods is/are used by a particular reference system. The reference system „Educational Media" uses as a teaching method … (a) lecture, (b) tutoring, (3) project-based teaching, (4) seminar, (5) internship, (6) tryout, (7) practice.

Example of a task requiring consideration of 2 functional relationships
You are searching for an e-learning reference system where the teaching method „Lecture“, and the communication technology „Video conference“ are applied in conjunction. Which of the following information resources may contain relevant information? (1) Teleteaching im Thüringer Verbund, (2) Educational Media, (3) Teleteaching, (4) Bubble Sort, (5) Pharmasquare, (6) COLAC, (7) DOIT.

Example of a task requiring consideration of 3 and more functional relationships
You intend to offer a “blended learning” seminar. As communication tools you want to use a cooperation tool for Web-based cooperative text design as well as audio conferences and e-mail. You are searching for an appropriate reference example to learn more about how to use these technologies. Which of the following resources would you choose get more information? (1) Teleteaching im Thüringer Verbund, (2) Educational Media, (3) Teleteaching, (4) Bubble Sort, (5) DOIT, (6) COLAG, (7) Pharmasquare.

The concept list and the concept map interface were developed by using the CmapTools concept mapping software (http://cmap.ihmc.us/). They both represented categorical relations between concepts visual-spatially in a tree-like hierarchical structure. However, in contrast to the concept list; the concept map also represented functional relations by means of labelled and directed links. That is, in the concept map hierarchical relations between concepts are represented in a visual-spatial mode as well as in a verbal mode by using link labels like “is a type of” or “is an example of”. In the case of the concept map the subjects could directly infer the relevance of an information resource by considering the category and the functional relations represented in the map. If desired, they could, however, also access the task-relevant resources and search for information relevant for coping with a task. In the case of the concept list inferring a relation was only possible for questions requiring consideration of a category relation. If a question which required the consideration of one or more functional relations had to be answered, information seekers using a concept list first had to search the relevant information by accessing potentially relevant Web pages and looking up the information in the text. Subjects in both experimental conditions could access an information resource by clicking at a corresponding concept node in the provided interface.

3.1.4 Procedure

In a first phase all subjects were administered two questionnaires. The first one was for assessing demographic data, and the second one was for assessing user prerequisites, such as computer- and mapping-experience, preferences for processing textual or graphical information, or prior knowledge on e-learning technologies (5 test-items). In the second phase, after brief instruction about the information seeking scenario, the users were presented a questionnaire with multiple choice questions. Each question was asking for a decision on which of the information resources listed would possibly contain relevant information to enable the participant to answer the question. In order to assess the effectiveness of the two interfaces, two basic dependent variables were used: time needed for answering questions of a particular question type *and* number of correct answers. Time for answering each question was recorded automatically by the mapping tool. In phase three, a short questionnaire was administered to assess perceived cognitive load.

3.2 Results

An analysis of the statistical premises showed that ANOVAS could be used for hypothesis testing. The results are as follows:

Hypothesis 1 was confirmed: Search time and correctness of decisions using a concept map interface or a concept list interface did not differ for answering questions requiring the consideration of category relations. In this condition, for deciding about the task-adequateness of a particular information resource, there were no statistical differences at a level of $p<0.05$ between subjects working with either the concept map or the concept list with respect to time for search and number of correct answers (search time: M_{CM} = 3:24:38; M_{CL} = 5:04:36; F(3,629); p<0.07; number of correct answers: M_{CM} = 14.39; M_{CL} = 14.48; F(0,021); p<0.89)).

Hypothesis 2 was partly confirmed: In order to answer questions requiring the consideration of one, two or three functional relations between concepts for deciding about the task-adequateness of a particular information resource, there were varying statistical differences between subjects working with the concept map as compared to subjects working with the concept list with respect to time for search and correctness of search results. The results were as follows: Search time, one relation: M_{CM} =3:06:00; M_{CL} = 7:06:36; F(57,96); p<0.001 (s); search time, two relations: M_{CM} =3:36:49; M_{CL} = 5:56:00; F(35,00); p<0.001 (s); search time, three and more relations: M_{CM} = 10:02:20; M_{CL} =11:09:03; F(0,26); p>0.05 (ns); number of correct answers, one relation: M_{CM} = 21,09;

M_{CL} = 19,29; $F(9,71)$; $p<0.003$ (s); number of correct answers, two relations: M_{CM} = 41,00; M_{CL} = 40,57; $F(0,54)$; $p>0.05$ (ns); number of correct answers, three and more relations: M_{CM} = 20,74; M_{CL} = 19,52; $F(10,37)$; $p<0.01$ (s). Subjects working with the concept maps had a significantly lower *search time* when they had to consider one or two functional relations, as compared to subjects working with the concept list. However, when three and more functional relations had to be considered, there was no significant difference in search time between users of the concept map and users of the concept list. As to the number of *correct answers,* only when one or three and more relations had to be considered the concept map was more effective than a concept list. When two conditions had to be considered, subjects working with the concept map interface did not significantly differ from subjects working with a concept list interface.

Hypothesis 3 was confirmed. When category relations had to be considered, the evaluation of the perceived cognitive load of users working with the concept map did not differ significantly from the evaluation of concept list users (M_{CM} = 2,13; M_{CL} = 2,19; $F(0,02)$; $p>0.05$ (ns)).

Hypothesis 4 was partly confirmed: When functional relations were in focus, subjects using the concept map reported significantly less cognitive load when one or three and more functional relations had to be considered (one relation: M_{CM} = 2,09; M_{CL} = 3,00; $F(6,42)$; $p<0.05$ (s); three and more relations: M_{CM} = 3,65; M_{CL} = 4,76; $F(8,47)$; $p<0.01$ (s)). However, when two functional relations had to be considered, there was no statistical difference between subjects using the concept map as compared to subjects using the concept list (M_{CM} = 3,30; M_{CL} = 3,90; $F(2,17)$; $p>0.05$ (ns)).

4 Discussion

The goal of the experiment was to study the effectiveness of a concept map as opposed to a concept list as an interface for fostering information search performance. Earlier studies (Weideman & Kritzinger, 2003; Goumi et al., 2003) had yielded contradictory results. It was criticized that in the study of Goumi et al. crucial features of a concept map as an interface for fostering information search had not been adequately used so that the potential of concept maps did not come to bear. It was assumed that the strength of concept maps lay in the explicit verbal cueing of semantic relations. If a concept map capitalized on semantic relations between concepts (topics) for cueing the task-relevance of information resources, performance in both information search and usability ratings would be enhanced.

In the present study, the effectiveness of a concept map and a concept list was studied. Both interfaces represented category relations quite similarly visual-spatially in a hierarchical structure. However, in the concept map interface functional relations between information resources were additionally represented explicitly in a verbal and visual-spatial mode and could be "read off", whereas in the concept list interface the relations between information resources had to be inferred from the text contained in the information resources. The results of the reported experiment show that, contrary to suggestions of Goumi et al. (2003), concept maps can be used successfully as interfaces for helping in the search for information resources if certain conditions are right: if the knowledge about semantic relations between the topics of the resources is relevant for information search, if the semantic relations are represented explicitly in a visual and verbal mode, if the concept map is comprehensible and easily usable. The results indicate that if only category relations are relevant for making decisions on the task-relevance of information resources, then a hierarchically structured concept list may be equally effective as a hierarchically structured concept map. Apparently the verbal labelling of relations in the concept map interface has no added value for category relations. If, however, functional relations are the primary focus, concept map users in most cases outperform concept list users.

Further research has to study in more detail why subjects using the concept map interface had a lower search time and more correct answers in some conditions but not in others. As to the perceived cognitive load, the results indicate that cognitive load is the same when using a concept map or a concept list, if category relations have to be considered. In this case, cueing the task-relevance of resources in a visual-spatial mode seems to be sufficient for fostering information search. However, if functional relations between concept nodes have to be considered for deciding on the task-relevance of information resources, the concept map users reported less cognitive load. A plausible explanation is that the combination of verbal and visual-spatial semantic cueing of the task-relevance of resources helps users to make sense of external representations, in turn making possible a knowledge-based information search. This seems to foster processes of external cognition (Scaife & Rogers, 1996) and, hence, to contribute to reducing cognitive load - provided that basic design criteria for clarity and comprehensibility of concept maps are met (Wiegmann et al., 1992).

We suggest that research on concept maps used as interfaces should focus on explicit semantic cueing and knowledge-based information search. Visual-spatial semantic cueing of the category structure inherent in an information repository may not always be enough to foster information search. Information visualizations “need to be tailored and augmented to focus attention on the task-relevant information“ (Sebrechts, 2005). Keeping in mind this suggestion, digital concept maps used as interfaces for fostering information search should not merely represent category relations of a content structure, as in many approaches on information visualization. They should explicitly represent, in a combined verbal and visual-spatial representational mode, those relations between concepts which have been identified in a task analysis as relevant for coping with a particular task and which have been selected for visual-spatial representation. It is suggested that concept maps used as interfaces for information search may overcome some of the shortcomings of pure visual semantic cueing in the traditional information visualization approach (Tergan, Keller & Burkhard, 2006). They might therefore be used successfully in resource-based learning, problem solving and counselling scenarios.

For future research we suggest that the differential effects of the visual-spatial and the verbal mode for representing different kinds of semantic relations in concept maps be analysed in more detail as to information search efficacy. Digital concept maps have not been studied much as interfaces for information search. However, because coping effectively with information resources in a diversity of resource-based educational and workplace settings will become a more and more important competency, in future research and application concept maps as interfaces used for fostering information search should receive much more attention.

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DOES THE FORM OF CONCEPT MAP NODES MATTERS?

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Abstract. Two studies examine the effect of the geometric forms of nodes of a concept map, presented prior to reading a text, on its comprehension. In the first study we varied the map interface. 162 students received a concept map to study. The map was presented in one of five interfaces: two bi-form interfaces (ellipses for content and rectangles for structure concepts, and vice versa), two uniform interfaces (ellipses or rectangles node frames), or a concept map without frames. Then a text was given to study without the map, and a comprehension test followed. Three texts were studied. The results indicated no comprehension differences between the two bi-form groups and neither between the two uniform groups. The comprehension scores were higher for the bi-form compared with the uniform interface. The no frame interface received the lowest scores. Before and after studying the texts, the students ranked their preferences for the various map interfaces. The preferences were in concordance to the overall comprehension results, regardless to the group conditions. In the second study we also compared an incongruent bi-form map to the other conditions using the same procedure. Incongruence hindered comprehension and was least preferred.

1 Introduction

In our work on concept mapping we noticed that the maps used by researchers and practitioners consist of concepts that are framed in rectangles, circles or other geometric forms. In our particular application of Text Concept mapping (Nathan & Kozminsky, 2004), we even use two forms to distinguish between content and structure concepts. We ask does form matters at all? Is a particular geometric form preferred in comparison to another form? Is a congruent assignment of form to nodes according to some predefined epistemology important? Therefore, in this study we examine the effect of the geometric forms of a concept map's nodes, presented prior to reading a text, on its comprehension. We also examine the preference of students to particular forms of nodes.

A concept map is a visual graph comprised of nodes containing concepts (verbal or visual descriptions) with links among them. The links are in the form of a line or an arrow with a verbal description (Gaines & Shaw, 1995). The nodes can assume various graphic shapes, depicting various types of information. The design of a concept map, which is based on Gestalt principles (affinity between concepts perceived also via distinguishing color, shape, and clustering), can make learning easier (Wallace, West, Ware & Dansereau, 1998). The visualization of mapping as an external representation, supplies cognitive support and reduces cognitive load from the learners' working memory (Sweller, 1994). The off-loading process enables the learners to invest more cognitive resources in the comprehension processes, thus leading to more meaningful learning (Novak, 2004). In this sense, concept mapping can be regarded as a mindtool (Jonnasen, 2000).

In our version of text's concept mapping, we distinguish in the map between *structure node*s that depict structural-rhetorical information of the text, and *content nodes* that contain the main content of the text (Nathan & Kozminsky, 2004) (see Figure 1). This is accomplished by applying a regular geometric distinction (Kosslyn, 1989): rectangles are assigned to structure and ellipses to content information.

Several studies investigated the role of different spatial configurations and link characteristics of concept maps in learning; some of them also analyzed the effects of the learners' abilities. O'Donnell (1994) reported that the use of a vertically organized concept (knowledge) map brings about an improvement in the achievements of learners who possess low-vocabulary abilities, compared to the effect of the use of the horizontally organized map. Map orientation did not affect high-vocabulary students. Also, the map's spatial configuration, format and link structure, affects encoding and retrieval of information in the map and is mediated by the user's spatial and verbal abilities (Wiegmann, et. al, 1992). For example, the use of embellished links such as arrows, labels, and barbed lines eases the tasks being carried out by those possessing high verbal abilities compared to their performance with unembellished links. In contrast, embellished links hindered performance of those with low verbal abilities.

There is a tendency to use various geometrical forms to distinguish different epistemological information in maps (e.g. Holley & Dansereau, 1984; O`Donnell, Dansereau & Hall, 2002). This is also the case in our use of text concept mapping, where different forms represent structure and content information. We'll report about two studies. In the first one (Kozminsky, Nathan & Cohen, 2006) we asked whether the use of a bi-form interface concept map is advantageous to the use of a uniform interface when the maps are presented before studying a text. In the second study we asked in addition about the effect of using bi-form maps that the forms are incongruent with the text's structure.

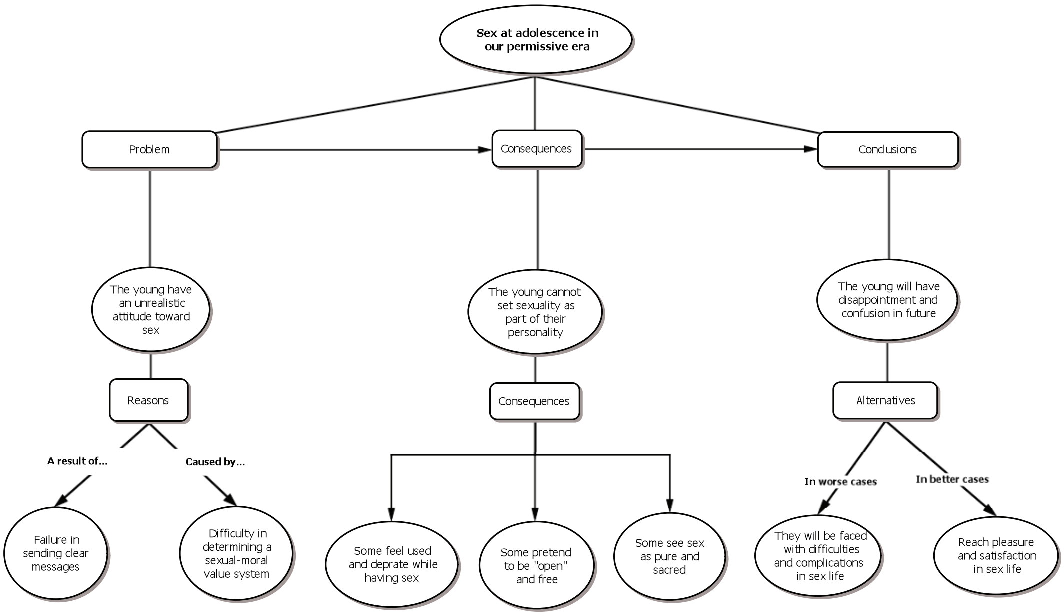

Figure 1: A text concept map. Ellipses represent content nodes and rectangles – structure nodes.

2 Study 1

162 students from an introduction to psychology course participated in the study. The students were randomly assigned into five experimental groups, each assigned a distinct map scheme: (1) Bi-form text maps: ellipses for content nodes, rectangles for structure nodes; (2) Bi-form text map: rectangles for content nodes, ellipses for structure nodes; (3) Uniform text map: rectangles for both types of nodes; (4) Uniform text map: ellipses for both types of nodes; (5) No frame: text map without a geometric forms surrounding content or structure nodes.

The study was conducted in three weekly sessions: In the first session, the students were randomly assigned to the five study groups and tested on reading comprehension, verbal and spatial abilities, and on their preference for a geometrical form of a concept map. All five map schemes for an example text were presented (see Figure 2), and the students were asked to rate their preferences for learning the text with each scheme on a 5-point scale (1-most preferred to 5-least preferred for learning).

In the second session, the researcher explained, separately to each group, the characteristics of the form the map and its components for an example text, according the group's study condition; then, the participants were asked to study another example text. First, they received for study the text's map for three minutes. Then they studied the text without the map (eight minutes); and finally, answered four questions (locating details, inference, identifying structure, and application, Raphael, 1982) without reference to the text or the map (six minutes), and received feedback about the correct answers. (2) In the third session, the students studied in their assigned groups three expository texts (235, 351, 540 words) with their text concept maps and answered four questions, in the same manner as they practiced in the second session. At the end of this session, the students were asked to provide again their preference for learning a text for each map scheme.

There was no statistically significant difference ($p < .05$ from now hence) among the groups in the initial reading comprehension, verbal and spatial ability scores. An analysis of variance was carried out on the overall comprehension scores of the texts and of each question type as a function of the various forms of the concept maps (see Table 1): (1) There was no statistically significant difference between the two bi-form groups and also between the two uniform groups; (2) Using concept map without geometric forms at all or a uniform interface, lead to lower comprehension compared with the bi-form groups. These differences were primarily manifested in memory for details and inference questions; (3) Using a bi-form map leads to higher comprehension scores than using a uniform map. These differences were manifested in memory, in text structure identification, and in application questions.

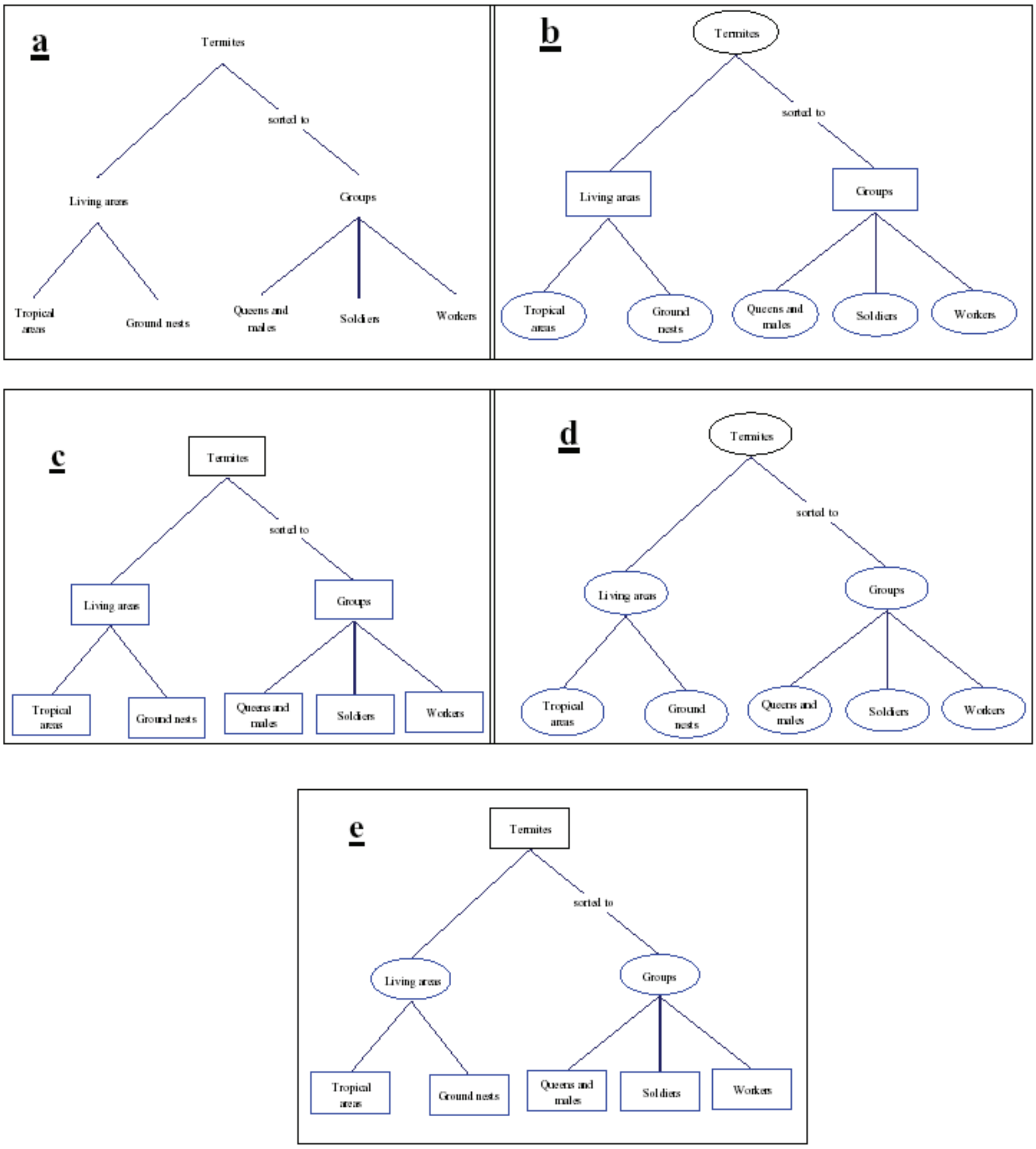

Figure 2. The five map schemes used the preference task. (a) No frame; (b) Bi-form maps: ellipses for content, rectangles for structure nodes; (c) Uniform text map: rectangles for both types of nodes; (d) Uniform text map: ellipses for both types of nodes; (e) Bi-form text map: rectangles for content nodes, ellipses for structure nodes.

The results support the hypothesis that a visual distinction between content and structure nodes in the map leads to comprehension improvement. This distinction was also preferred by the learners independent of their study condition. Therefore, there is congruence between the perceptual preferences and the cognitive performance.

So based on these results, we continued with a second study (which is still in progress), in order to verify whether the nodes' distinct functions and congruence affect text comprehension. Especially we questioned whether incongruent maps, in terms of form assignments to nodes' categories, will hinder comprehension and will affect perceptual preference.

Group	N	Total scores	Comprehension levels			
			Details	Inference	Structure	Application
I Content - ellipses Structure - rectangles	34	1.45 (0.27)	1.38 (0.39)	1.67 (0.38)	1.33 (0.35)	1.41 (0.54)
II Content - rectangles Structure - ellipses	34	1.39 (0.27)	1.49 (0.34)	1.63 (0.47)	1.31 (0.32)	1.14 (0.49)
III Content & structure rectangles	31	1.29 (0.34)	1.30 (0.30)	1.52 (0.48)	1.27 (0.44)	1.09 (0.55)
IV Content & structure rectangles	31	1.20 (0.34)	1.29 (0.27)	1.48 (0.27)	1.02 (0.36)	1.01 (0.55)
V No frames	32	1.16 (0.35)	1.14 (0.37)	1.33 (0.51)	1.09 (0.43)	1.09 (0.61)

Table 1: Adjusted mean scores (and standard deviations) in the comprehension test (range 0-2) for the study groups

As for map preference (see Table 2), there was a preference both before and after studying for a bi-form compared to a uniform or no-form interface.

Scheme	Before Intervention	After Intervention
I. Content – ellipses; Structure - rectangles	2.67 (1.25)	2.36 (1.27)
II. Content – rectangles; Structure - ellipses	2.50 (1.25)	2.31 (0.85)
III. Content & structure - rectangles	2.70 (1.14)	2.90 (1.14)
IV. Content & structure - ellipses	3.0 (1.15)	3.0 (1.00)
V. No frame	4.10 (1.49)	4.30 (1.25)

Table 2: Students' preference means for learning a text with each concept map scheme (N = 162)
before and after the intervention (1-most preferred to 5-least preferred)

3 Study 2

43 students from an introduction to psychology course participated in the study. The students were randomly assigned into five experimental groups: (1) Congruent bi-form text maps: ellipses for content nodes, rectangles for structure nodes; (2) Uniform text maps: rectangles for both types of nodes; (3) Incongruent bi-form text maps: ellipse and rectangle forms, in their proportion to Condition 1, were randomly assigned to the map's nodes; (4) Text maps without any geometric forms surrounding content or structure nodes; (5) No map. The

procedure was as in Study 1. In the No Map condition the time allotted to study a text was a sum of the times allotted for map and text study in the map conditions. The students' preference for a geometrical form of a concept map was tested in concordance to the conditions of the second study. All four map schemes for an example text were presented (congruent bi-form, uniform, incongruent bi-form, and no frame), and the students were asked to rate their preferences for learning the text with each scheme on a 4-point scale (1-most preferred to 4-least preferred for learning).

The comprehension results exhibited a trend similar to Study 1 (not yet a statistical one). Especially we note that comprehension results following exposure to an incongruent or to a no-frame maps tend to be lower than the bi-form and uniform conditions. The preference results (see Table 3), also provided a similar (statistically significant) trend as was in the first study. In this study the order of preference was from the congruent bi-form, uniform. Incongruent bi-form, and no frame.

Scheme	Before Intervention	After Intervention
Congruent bi-form frame	1.86 (0.94)	1.71 (0.87)
Uniform frame	2.05 (0.87)	2.01 (0.85)
Incongruent bi-form frame	2.88 (1.25)	2.85 (0.99)
No frame	3.28 (0.91)	3.41 (0.53)

Table 3: Students' preference means for learning a text with each concept map scheme (N = 43) before and after the intervention (1-most preferred to 4-least preferred)

4 Discussion

We found in the first study that using a bi-form map leads to higher comprehension scores than using a uniform or a no-frame map. There was also a perceptual preference both before and after studying for a bi-form interface compared to a uniform one. The no-frame map received the lowest preference score. We propose that the bi-form concept map compared with the uniform map reduces "cognitive load" by providing additional information regarding the semantic role of each node type, and thereby releasing working memory resources for higher level thinking and study activities (McAleese, 1998). This "cognitive load" reduction is also noted by the learners as a perceptual preference for a bi-form interface. By a similar reasoning, we propose that incongruence introduces additional cognitive load, requiring the learner to decipher the nodes' correct roles.

As for explaining the frame/no frame effect we have to resort to basic attention theory. First, several examples of students explaining their perceptual preferences: "The bi-form map is the most preferred, since the different shapes have a different meaning, and this is not so in the other formats." "In the bi-form map subcategories are more noticeable." "A uniform format is more pleasant to the eye." "Better to study when the nodes are framed." The students' explanations refer either to some perceptual qualities (pleasant) or to the ease of locating information and assigning meaning conveyed by the frame. Intuitively, we understand that in complex maps, retaining only verbal labels can cause location confusion and lead to misreading of concepts, especially in scan mode. So, geometrical frames surrounding concept may improve distinction or memory for location (LaBerge, 1995), that are selective aspects of attention. Also the regular interpretation of the geometrical shapes, tunes the sensitivity control components of the attention system (Knudsen, 2007), so the comprehension is facilitated. More time can be dedicated to higher thinking processes.

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EFFECT OF THE NATURE OF THE FOCUS QUESTION ON PRESENCE OF DYNAMIC PROPOSITIONS IN A CONCEPT MAP

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Abstract. The effective use of concept maps in education has been limited by a generalized tendency amongst learners to construct descriptive concept maps, characterized primarily by static propositions. Adequate representation of knowledge, however, calls for both description and explanation, that is, a combination of both static and dynamic propositions. This is especially true of scientific and mathematical reasoning, where dynamic relationships are necessary to establish interdependencies and covariation among two or more concepts. Experiments have shown that dynamic focus questions significantly increase the presence of dynamic propositions in concept maps. The results presented in this paper confirm this finding, and suggest further that the two vary in direct proportion to one another, that is the more open and dynamic the focus question, the more dynamic the resulting propositions.

1 Introduction

At the closing of the Second International Conference on Concept Mapping, in Costa Rica, Cañas & Novak (2006) called for a re-examination of the foundations of concept mapping in order to make better use of the tool. In their address they noted that in spite of the increased usage of concept maps worldwide, much of the tool's representational power continues to be lost to most users.

One of the reasons identified by Cañas & Novak (2006) is the tendency, pervasive among mappers, to construct descriptive concept maps, as opposed to explicative maps. This in turn appears to be the result of focusing on objects rather than events. According to these authors, concept maps that deal with objects generally end up being descriptive maps, characterized almost entirely by static propositions; in contrast, concept maps that involve events are usually more explanatory and contain more dynamic propositions.

Derbentseva, Safayeni, & Cañas (2004), for their part, have pointed out that in general adequate knowledge representation requires both static and dynamic propositions, as it is the latter that capture covariation and changing relationships among two or more concepts. This assertion is especially true for scientific and mathematical knowledge, where causal relationships and interdependencies among two or more variables often show up. Thus, propitiating dynamic propositions in concept maps is a most desirable goal.

Recently, Derbentseva, Safayeni, & Cañas (2006) experimented with two different strategies to increase the number of dynamic propositions in a concept map. One approach involved quantification of the root concept, while the other involved experimenting with the nature of the focus question. For the purpose of the present article, we center our attention on the second strategy, namely, on the relationship between the nature of the focus questions and the kinds of propositions that show up in a concept map.

As Novak & Cañas (2008) indicate, focus questions make explicit the questions or problems which concept maps are supposed to address. In this manner focus questions help direct the learner's attention to the issue under consideration. Additionally, since hierarchies among concepts and relationships are highly context dependent, focus questions help establish a specific context within which to rank and relate concepts, thereby guiding concept map construction.

According to Novak & Cañas (2008), the nature of the focus question influences the type and quality of the resulting concept map. The study by Derbentseva *et al*. (2006) provides evidence that this is indeed the case. In their research they compared a focus question asking "what is concept X?" with a focus question asking "how does concept X work?" Their results showed that the "how" condition produced significantly more dynamic propositions than did the "what" condition.

In this paper we present evidence that substantiates the findings of Derbentseva *et al*. (2006). Our results suggest, furthermore, that the more open and dynamic the focus question, the more dynamic the nature of the resulting propositions, i.e., that there may be directly proportional relationship between the two variables.

2 A classification of focus questions

In considering types of focus questions two criteria were considered: first, the degree to which a question admits a variety of answers across different individuals, that is, how open to personal input a question is; and second, the degree to which the answer requires explanation through dynamic propositions. With these criteria, focus questions were classified as: 1) closed or classificatory, 2) open-static, and 3) open-dynamic. Closed or classificatory questions tend to have a universally accepted answer and therefore do not allow much variation among respondents. Maps responding to this type of question tend to be quite similar to one another, as room for personal input is minimal. Examples of this type of question are *"What are the layers of the Earth?"* or *"How is Panama divided politically?"* Open-static focus questions generally request descriptions of concepts. They admit a variety of responses, since personal experience can be incorporated into these descriptions; however, they tend to lead to maps that depict unchanging relationships, i.e., maps that are basically static in nature. Examples of these kinds of questions are *"What is magnetic resonance?"* or *"Who was Picasso?"* Finally, open-dynamic focus questions generally deal with events, rather than objects, and go beyond requiring mere descriptions to demanding reasons and explanations for these events, be they situations or happenings. Maps responding to this type of question account for changing relationships and interdependencies among concepts, hence their overall dynamic nature. Furthermore, responses vary greatly among learners, since personal experience and understanding plays a major role in map construction. Examples of open-dynamic questions are *"Why do birds migrate?"*, *"Why is it important for pregnant women to ingest folic acid?"*, or *"How does an airplane fly*?" As can be appreciated, the classification proceeds simultaneously from less openness to more openness, and from requiring fewer dynamic propositions to requiring more. Also, one can see that the typical "What is...?" focus question tested in Derbentseva *et al*.'s study falls in the open-static category, whereas the "How does...?" question pertains to the open-dynamic class.

3 Dynamic propositions

Safayeni *et al*. (2004) define dynamic relationships as those that establish implication, functional interdependence and covariation among the concepts. Static relationships, on the other hand, "describe, define and organize knowledge for a given domain" (ibid, p. 10). In our work, dynamic propositions are defined slightly differently: we consider a proposition to be *dynamic* if it involves 1) physical movement, 2) action, 3) change of state, or 4) it establishes some form of dependency or causal relationship. Propositions that are not dynamic are *static*.

We further classify dynamic propositions as causative or non-causative. In order for a dynamic proposition to be causative, one part of the proposition must embody the "cause" or "probable cause," while the other part must correspond to the "effect." Alternatively, one part of the proposition must be identifiable as the "source" from which that which the effect stated in the other part of the proposition originates. In non-causative dynamic propositions no such identification is possible. The propositions given below exemplify these three types of propositions:

- Examples of static propositions:
  - *The sun is a star*
  - *Means of transportation include land transport*
  - *Panama is located in Central America*
  - *Animals may be vertebrates.*

- Examples of non-causative dynamic propositions:
  - *Roots absorb water*
  - *Herbivores eat plants*
  - *Living beings need oxygen*

- Examples of causative dynamic propositions:
  - *Cigarettes produce cancer*
  - *Rule of law attracts foreign investment*
  - *Heat melts ice*
  - *Paper comes from trees*

Causative propositions, in turn, may be divided into quantified or non-quantified. Quantified causative propositions explicitly indicate the manner in which a certain change in one concept induces a corresponding change in the other concept, unlike non-quantified propositions that make no reference to directionality or any other measure of the causal relationship. The following examples help clarify these distinctions:

- Examples of quantified causative dynamic propositions:
  - ***Increased*** *transparency in public affairs* ***discourages*** *corruption*
  - ***Under-activity*** *of the thyroid gland* ***decreases*** *body metabolism*
  - ***Increased*** *quality of education* ***contributes to greater*** *national development.*

In evaluating the dynamic nature of the propositions, the specific categories considered were the following: 1) only static propositions are present in the concept map (there are no dynamic propositions of any kind), 2) only non-causative dynamic propositions, 3) one to two causative dynamic propositions, 4) more than 2 causative dynamic propositions, and 5) one or more quantified causative dynamic propositions. This sequence of categories attempts to reflect an increasing degree of explanation in propositions. Static propositions, for instance, do not explain, they describe structural aspects of concepts. Non-causative dynamic propositions also are not explicative; rather they tend to describe functional aspects of concepts. Causative dynamic propositions, in contrast, explain how one concept produces or results from another; quantified causative dynamic propositions, additionally, provide a direction or measure of the covariation between cause and effect, that is, they explain how change in one concept cause changes in the other. Thus, according to this description, the more dynamic a proposition the greater its explanatory nature.

4 Methods and procedures

The results presented here were obtained as part of a larger research program that investigated the acquisition of skill in concept mapping by in-service Panamanian public elementary schoolteachers participating[1] in Panama's *Conéctate al Conocimiento* Project (see Tarté, 2006). To this end, initial and final concept maps created using CmapTools[2] (Cañas *et al*., 2004) were gathered via the CmapTools Recorder feature (Miller, Cañas & Novak 2008). The sample was obtained from 18 different training groups, taught by different pairs of Project facilitators over the course of a 3-month period extending from July through September 2006, and ended up consisting of 258 teachers. For both these maps teachers worked individually. Topics for the final map were freely chosen by the teachers; for the initial map, topics were chosen in 14 of the 18 groups, while in the remaining 4 groups maps were based on an assigned reading. In all cases teachers posed their own focus questions. Time allotted for map construction varied among training groups, but generally was between 1.5 – 2 hours. However, some teachers stopped before the time was up, while others continued working afterwards.[3] Thus, mean construction time for the first map was 1 hour 32 minutes, and 1 hour 58 for the final map.

Completed Cmaps were analyzed using the taxonomy for concept maps developed at the Conéctate Project. This taxonomy consists of a topological taxonomy (Cañas, Miller, Novak *et al*., 2006), used to evaluate concept maps in terms of their structure, and a semantic scoring rubric (Miller & Cañas, 2008), to evaluate content. In addition to overall semantic evaluation of Cmaps, specific semantic elements such as focus questions, dynamic propositions and cross-links were scrutinized. This paper reports the results of the examination of focus questions and dynamic propositions, as well as the relationship between them.

At the Conéctate workshops focus questions are viewed as an important component guiding concept map construction. They provide not only a context for the map, but a specific query, problem or issue which the map must address and respond to. Facilitators in charge of teacher training introduce focus questions from the very first day of the workshop. Though specific remarks evidently depend on individual facilitators, most comments would have been aimed towards emphasizing their guiding/contextualizing role, and getting teachers' maps to answer the focus question.[4] Some facilitators may have gone a bit further, and encouraged teachers to pose questions outside the school curriculum, about topics pertaining to their everyday lives or subjects of general interest to them. One can be certain however that no mention would have been made about the classification described above, for the simple reason that it was unknown to the facilitators themselves.

Regarding dynamic propositions, most facilitators have been exposed to the term through the involvement of Cañas and Novak in the Conéctate Project, and their presentation at CMC 2006 (Cañas & Novak, 2006). However, the definition of dynamic proposition presented here, as well as the classification of concepts from

[1] It should be pointed out that the selection of teachers and schools to participate in the workshops, and the assignment of teachers to training groups, were beyond the control of the researchers.
[2] We denote concept maps created using CmapTools as Cmaps.
[3] Some would work during part of their coffee breaks or lunch period.
[4] Novak & Cañas (2008) have remarked on learners' tendency to veer away from the focus question and construct concept maps that respond to some other question, rather than the one originally put forth.

least to most explanatory, were and continue to be unfamiliar to all but a few of the facilitators. Moreover, the general idea of dynamic proposition at present is not a topic discussed in the Conéctate workshops. For all these reasons, one can rest assured that teachers were not familiar either with the notion of dynamic proposition, and much less with the categorization we made of them.

5 Results

Cmap Figure 1 displays the distribution of focus questions on the initial and final Cmaps, according to the classification given above. In both cases the distribution was centered on the open-static category; however, there was less dispersion in the final Cmap. It is interesting to note, that the overall the percentages in the closed/classificatory and open-dynamic categories remained virtually unchanged from one map to the other. However, as can be seen, the narrowing of the range in the final map resulted from a decrease of maps with no focus question and an increase of maps with open-static focus questions.

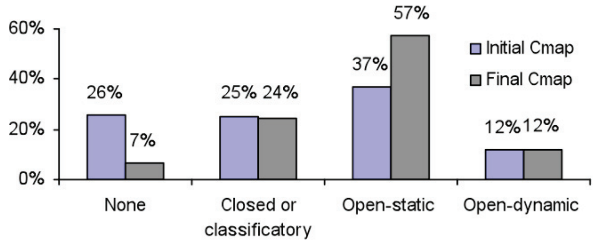

Figure 1. Distribution of focus questions in initial and final Cmaps.

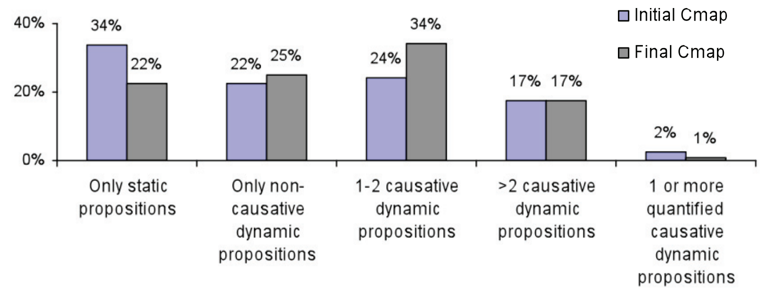

Figure 2. Distribution of dynamic propositions in initial and final Cmaps.

A corresponding analysis was carried out for dynamic propositions (figure 2). The graph shows a similar distribution pattern for dynamic propositions in the initial and final Cmaps. Both are characterized by a relatively uniform distribution across the first four categories, contrasting with the absence of propositions in the fifth category, the class of quantified causative dynamic propositions. The main difference between the two maps was a shift to the right, accounted for mainly by the decrease in the category of only static propositions and a corresponding increase in the 1-2 causative dynamic propositions category. Despite the decrease in the first category, there still remains in the final Cmap a considerable fraction (22%) with only static propositions in them. Likewise, close to half the maps (47%) contain no cause-effect propositions.

Next we explored the relationship between the type of focus question put forth (independent variable) and the dynamic nature of the propositions present in the concept map (dependent variable). To investigate this relationship analytically we made use of ordered logit regression analysis, since the two categorical variables have a “natural” ordering. The “goodness of fit” probability was 0.09 on the initial Cmap and 0.00 on the final Cmap. Thus, the null hypothesis – that there is no relation between the type of focus question and presence of dynamic propositions – is rejected in favor of an association between the two variables. The probability values suggest a weaker association in the first Cmap and a stronger one in the final map.

These results can be observed graphically by inspection of figures 3 and 4. If one were to envelope all four categories of focus question under a single bell-shaped curve, one would notice, in the first Cmap, that the center hovers somewhere between the closed/classificatory and the open-static category, and the distribution has a fairly high variance; in contrast, in the final map the mean lies farther to the right, above the open-static category, and there is much less variance in the distribution.

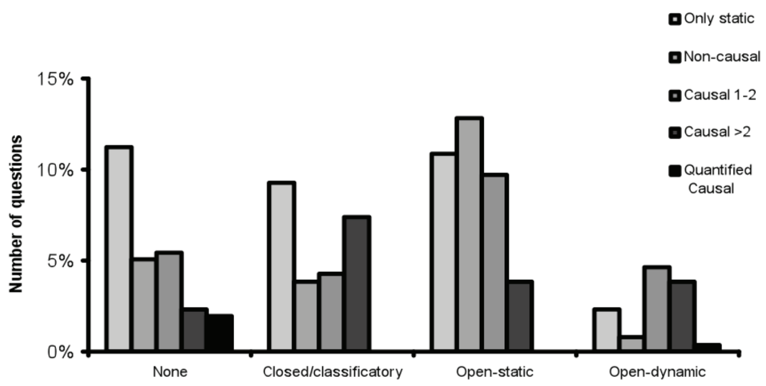

Figure 3. Relation between focus question and propositions present in initial Cmap.

If one looks across the different categories one also notes a certain pattern: the center of imaginary bell curves superimposed over each of the 4 categories moves farther to the right as the category moves to the right. This pattern is more pronounced and evident in the final map. What this suggests is that as the focus question becomes more open and requires more explanation to answer it, the propositions indeed become increasingly explicative.

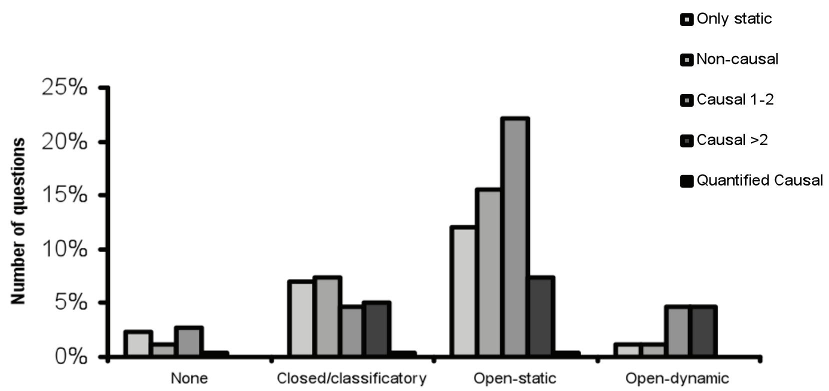

Figure 4. Relation between focus question and propositions present in final Cmap.

Finally, and along the lines of Derbentseva *et al.*’s (2006) study, we compared the presence of dynamic propositions, specifically causative statements, in Cmaps with open-static versus open-dynamic questions. The contingency table in figure 5 shows our findings. What we see is that open-static questions lead to a relatively equal distribution of causative and non-causative proposition; whereas, open-dynamic questions lead to more causative propositions in a ratio of 4 to 1.

		Nature of propositions		
		Non-causal	Causal	Total
Type of focus question	Open- static	71	77	148
	Open-dynamic	6	24	30
	Total	77	101	178

Table 2. Contingency table showing a significant association ($P = 0.005$) between type of focus question and presence of causative dynamic propositions in a concept map.

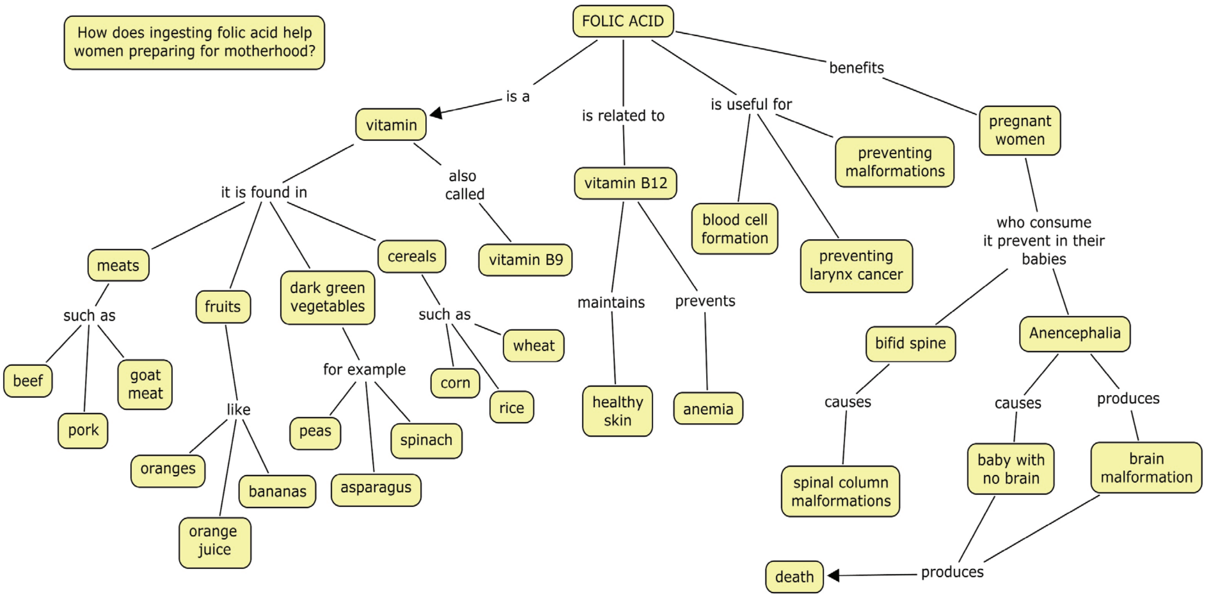

Figure 5. Concept map associated to an open-dynamic focus question: *"How does ingesting folic acid help women preparing for motherhood?"*

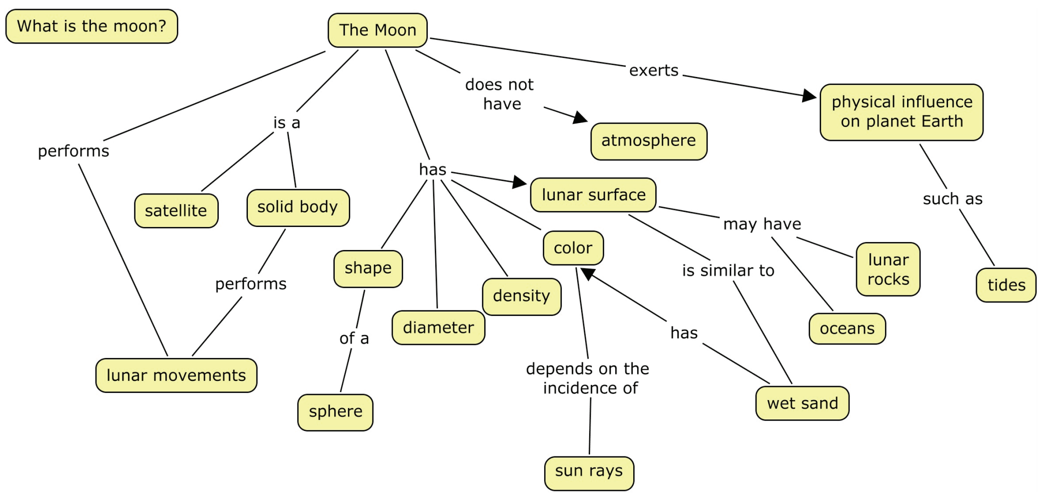

Figure 6. Concept map associated to an open-static focus question: *"What is the Moon?"*

Figures 5 and 6, respectively, show examples of rather typical Cmaps associated with open-dynamic and open-static focus questions. In the map corresponding to the open-dynamic question, of a total of 20 propositions (examples excepted), there are 12 causative dynamic propositions. In contrast, in the map associated to the open-static question, of a total of 18 propositions (there are no examples) there is only one that is causative.

6 Discussion

Concerning the type of focus question, results indicate a significant decrease in the number of maps containing no focus question and a corresponding increase in those with open-static focus questions. These findings were to be expected given the emphasis placed by facilitators on the importance of including focus questions in concept maps, and the encouragement given to considering topics outside the school curriculum, and closer to personal experience.

Results also reveal changes in the nature of questions, in particular the decrease of static propositions and parallel increase of causative propositions. Unlike changes in focus question, these results can not be attributed to facilitator intervention. As pointed out earlier, though most facilitators have been exposed to the notion of dynamic propositions, this is not a topic they are intimately familiar with, and it is not one that is covered in the workshops. Furthermore, the classification of propositions in terms of their explanatory nature was not known to them. In view of this, the distribution of propositions both in the initial and final maps, as well as any change in this distribution between the two maps, must follow, at least in part, from the type of questions guiding the construction of the maps.

We have seen that there is a clear positive association between the type of focus question and the nature of the propositions. In particular, the more open to personal experience and the more demanding of explanation a focus question, the more explicative the resulting propositions in the corresponding concept map. This finding confirms the result obtained previously by Derbentseva *et al.* (2006). However, it goes a bit beyond as well. Derbentseva el al.'s (2006) experiment compared two specific questions, a "what is..." question with a "how does..." question, which belong to our open-static and open-dynamic categories, respectively. In our setting, 258 virtually different questions[5] posed by an equal number of subjects were considered. Thus, our data essentially generalizes the previous result, showing that it holds true, independently of any particular question.

7 Conclusions

In this paper we have presented results confirming and generalizing an earlier result by Derbentseva *et al*. (2006) concerning the effect of the focus question on the dynamic nature of propositions in a concept map. We have shown that the more open to individual input and the more demanding of explanation the focus question, the more dynamic (explicatory) the nature of the resulting propositions.

If we are to take full advantage of concept maps as a tool for meaningful learning, especially with regard to the sciences, we must promote explicative maps, containing numerous dynamic propositions. The significance of this result rests in the possibility of achieving this increased representational power of concept maps. It demonstrates that by simply posing a certain kind of question, one that demands both an explanation and an evocation of personal experience, concept maps will naturally tend to incorporate more dynamic propositions. If this is accompanied by additional questions, particularly dynamic questions, concerning the relationships between pair of concepts, the explanatory potential of concept maps and their value as a Mindtool may be significantly increased.

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[5] It may have been that, coincidentally, some questions may have been repeated.

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EFFICIENCY OF CONCEPT MAPPING FOR THE CONCEPTUAL UNDERSTANDING OF *BURNING AND UNDERLYING PROCESSES OF COMBUSTION* FOR ELEMENTARY SCHOOL STUDENTS

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Abstract. The study shows the triangulation of qualitative and quantitative research methods on concept mapping. The research questions focus on two aspects: 1) How must the topic *burning and combustion* be educationally structurized to promote meaningful learning and 2) do elementary school students learn science concepts more efficiently by the use of Concept Mapping than with traditional linear methods.
Concept Mapping is used in this study as a) a qualitative research method to investigate student's conceptions about the specific content and b) as the object of interest in the investigation as they were quantitatively compared to a linear method to investigate the efficiency of concept maps in their function as a learning method. The aims of the study lay in the combination of findings to create guidelines for learners and teachers for their work with Concept Mapping within this domain specific content of chemistry education.

1 Introduction

In studies about how young children learn science concepts meaningfully it is often reported that they tend to have problems integrating new scientific concepts in established knowledge structures (Rahayu et al. 1999, Seré 2000). Thereby scientific knowledge stands isolated in opposition to "every-day" assumptions. Everyday concepts can have a great impact on observations and interpretation of scientific phenomena (Prieto 1992, Anderson 1990, Meheut 1982).

Additionally, Concept Maps are often described as "metacognitive tools" that support children's reflective thinking by using visual and conceptual representations (Mintzes et al. 1997). By creating and modifying a concept map the creator needs to make comprehensible decisions about which concepts are related or subordinated and in which context they are used. As processes of individual self-reflection, self-control and evaluation are necessary for creating a concept map, these processes will concurrently be positively influenced. Concept Mapping has been proved to be efficient for short-time memory of concepts (Bernd et al. 2000). Concept Mapping also exert an influence on long-time memory of knowledge concerning an overview of a domain area (Juengst 1995). A positive effect of the use of Concept Mapping could be reported for student's attitude in relation to science as they gain a transparent overview of domain specific knowledge fields (Jegede et al. 1990). So far it is not yet investigated how and in which extend the method of Concept Mapping has a positive influence on elementary school students learning alleged abstract concepts such as *burning and combustion*. According to these research interests, this study uses Concept Mapping as a) a research method and b) as the object of interest of the inquiry.

2 Design of the study

The study combines the interests of two different fields: the interest of pedagogical psychology in the efficiency of a certain learning method such as Concept Mapping and the reveal of underlying cognitive processes and the interests of science education in elementary students (pre-) conceptions about a special chemical phenomenon. The aim is, to combine the results of these two research fields in the background of a practical orientated research model to give advices for school learning.

Therefore the investigation focuses on two research questions:

1. How can the topic *burning and combustion* be structured for elementary school students?
2. Do children learn science concepts more efficiently by using networking learning methods such as Concept Mapping?

To answer these questions three parts of investigation were made:

a. By using interviews, experts identified the scientific (chemical) matter of the topic *burning and combustion* for elementary school students from their own experiences.
b. Qualitative analyses revealed the students' conceptions about the topic *burning and combustion* and have been related to other research results.

c. By using a special quantitative scoring the efficiency of Concept Mapping for learning the matter *burning and combustion* has been evaluated.

Two of the three parts of the study and their specific influence on the educational structuring process are described below.

The research is methodologically settled in the research frame of the underlying model of *Educational Reconstruction* (Kattmann et al. 1997). This model aims at the iterative connection of

- the clarification and simplification of the specific subject matter,
- the analyses of students' (pre-)conception about the specific topic and
- an educational structuration of the specific subject matter which constitutes the research target.

Epistemologically the model bases on constructivist ideas that assume the (re-)construction of a certain subject matter by the individual itself. As science education acts as a meta-science against domain specific science, it requires the inclusion of students' (pre-)conceptions as part and parcel in the process of (re-)construction. The following graphic shows the interaction of all research paradigm related to the specific parts of this study:

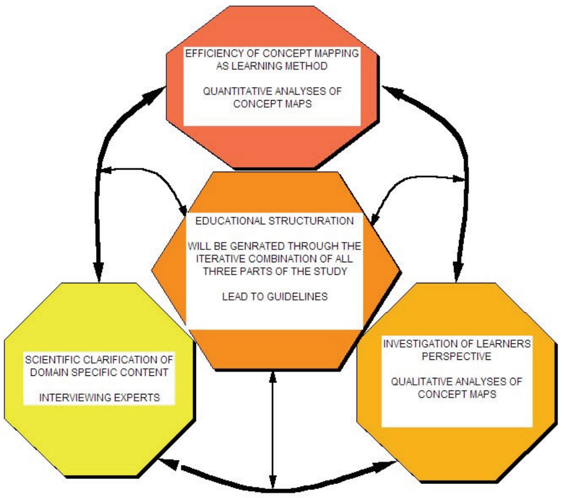

Figure 1: Design of research included in the research framework of the Model of Educational Reconstruction

The scientific clarification and the investigation of the student's (pre-)conceptions mark these parts of the study that are focused on the answering of the first research question, because they refer to the content *burning and combustion*. Here, two investigations were made which are presented under 2.1 and 2.2. Part 2.3 shows the results of the study about Concept Mapping as the focus of the investigation; this part is described more in detail as it is of greater importance for the aims of the study.

2.1 Clarification of specific subject matter by interviewing experts

The simplification of scientific matter, which is in this case the topic *burning and combustion*, marks one of the central aspects within the model of Educational Reconstruction (Kattmann et al. 1997). To identify concepts that are relevant for elementary school students, four experts have been interviewed. These experts all have a scientific background and have developed different educational submissions for elementary school students for the topic *burning and combustion*. The method of interviewing experts has often been used in qualitative research (Meuser 1994) and proofed its value. As it is not the focus of this overview the findings on that are omitted.

2.2 *Concept Mapping as research method – the investigation of student's preconceptions of the topic burning and combustion*

The Concept Maps of 92 elementary school students at the age of 10 have been evaluated qualitatively. As *burning and combustion* has not been discussed in school lessons these mapped concepts base on preconceptions.

This part of the study represents methodologically an empirical-qualitative exploration. First the data has been deductively related to results of studies in the field of science. In the qualitative analysis, theory-based aspects of the evaluation were related to the data, then deduced and in a formal-contextual way structurized sensu Mayring (2000). Second, the data has been searched for everyday concepts, which were collected indicatively. Through processes of generalization categories were identified and communicatively validated.

In the process of collecting the data, the propositions (a proposition consists of two concepts linked by a labelled relation) within the Concept Maps were analysed under the named procedures. Over all 118 concepts were counted and 9 different categories could be identified which should be mentioned here in detail:
Scientific concepts: The most prominent concepts were *wood as an example for a combustible material*, which forms 24% of all scientific concepts and therefore is one of the most prominent concepts and *water as a solution for extinguishing a fire* which was named 25 times and makes 21% of all scientific concepts. A lot of other examples for a burning material were also named (paper, coal and hay), but surprisingly the candle or the burnt wax was only named three times. Even two children noticed that a fire needs a *temperature for burning* and 12 named a *source of ignition* like lighters or matches.
Sensitive perception: The most frequently named sensitive perception was *fire is hot* (named 55 times). 9 times the *generated heat* was mentioned.
Destruction and dangerousness: The most important thing the students named under this aspect was that *fire is dangerous* and not that it can be dangerous if handled wrongly. They also mentioned fire to be *deathly*.
Description of the phenomena: Often the students knew that a fire *has a flame* (named 21 times) and *smoke occurs* (named 23 times).
Own experiences: What is outstanding within this class is the experience of *getting burnt*.
Aesthetic dimensions: Students often described the fire with certain qualities of *colour and smell*.
Institution fire station: Almost all students named the *fire station* and their responsibility for extinguishing fires.
Word associations: Special German words are mentioned like the fire station, but rarely.
Historic dimension: Twice the invention of fire by *prehistoric men* was mapped.

It is not surprising that elementary school students have more everyday concepts than scientific concepts. Remarkable, but well in line with other research findings is the fact that there is a dominance of concepts that describe *fire* as being dangerous and destructive (Prieto et al. 1992; Rahayu et al. 1999). These concepts even outweigh concepts that are based on own experiences. Working with scientific experiments can help to fill the gap of own experiences and can also influence the strong believe that *fire* is dangerous. Maybe making experiments can even help regarding *fire* as less dangerous if handled well and that it requires certain care.

The collection of "scientific" and "everyday" concepts through the research method of Concept Mapping and their utilization for Educational Structuration in the sense of the model of Educational Reconstruction has been innovative. Through the results, the effect of emotional affected concepts in this specific content and their great influence on learning processes could be demonstrated.

2.3 *Concept Mapping as the subject matter of the inquiry – efficiency of Concept Maps for elementary school students*

In the past, the method of Concept Mapping has been proven to be very effective for adult learners (Juengst 1995; Bernd et al. 2000) as well as for the use of learning strategies (Fischer et al. 2000) and diagnostical knowledge research (Stracke 2003; Weber et al. 2000). Contrary to some assumptions, even young children are able to produce meaningful concept maps (Novak et al.1983; Novak et al. 1984).

According to this, the third research question focuses on whether elementary school children learn more efficient by using networking learning methods such as Concept Mapping.

Students' cognitive abilities were investigated with the CPM-Test (Coloured Progressive Matrices by Raven). In form of guided inquiry learning, the students acquired the underlying chemical concepts of the topic *burning and combustion* which was embedded in an excursion to the students' chemical laboratory („CHEMOL"[1]) at the University of Oldenburg.

Subsequent to this, two cognitively homogeneous groups recorded their knowledge by either taking traditional keyword-list[2] (group A) or building up a Concept Map (group B)[3]. A follow-up multiple-choice knowledge test two weeks later was handed out to show the students overall conceptual understanding.

A quantitative evaluation analyses which of the two groups, the keywords-list-group or the Concept Map group, has learned more effectively than the other group. Therefore all data have been investigated with a specific score-code: In the key-word group all concepts have been counted, then the occurring misconceptions have been pointed out and finally the scientific concepts, which were taught in the intervention, have been counted. The same has been done for the Concept Mapping group, but additionally the frequency of cross links has been scored. These results have been compared with the data collected from the knowledge test by correlation testing. The following charts show an example of a before- and after-intervention Concept Map with the detected scoring:

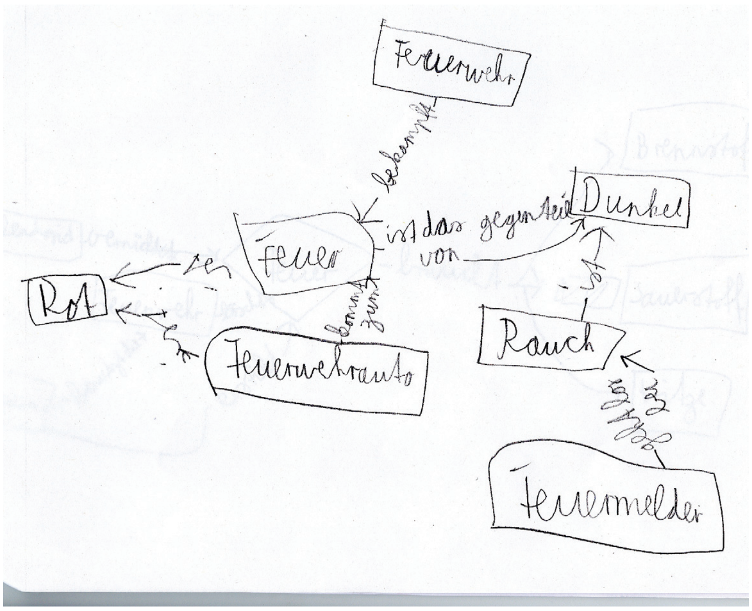

Figure 2: Max Concept Map before intervention

Translation:
Rot – red
ist - is
Feuer – fire
Feuerwehrauto – fire engine
kommt zum – comes to
Feuerwehr – fire brigade
bekämpft – fights against
ist das Gegenteil von – is the opposite of
dunkel – Darkness
Rauch – smoke
Feuermelder – fire detector
geht an bei – sounds the alarm when

Scoring:
All: 7
Scientific Concepts: 0
Misconceptions: 0
Crosslink: (7+1) 8

The most interesting results were the fact that the amount of used scientific concepts within the Concept Maps correlate positively on the score of the knowledge-test (r=.30*,N=48). And the level of networking within the Concept Maps also correlate positively on the score of the knowledge test (r=.80**,N=17). While the results show that the level of cognitive ability of the students had no influence on the possibility to learn effectively with the method of Concept Mapping it can be used in educational surroundings to emphasize the scientific concepts and their function for burning processes. The degree of deeper understanding can be promoted through a directed use of certain concepts and the intention of maximum linking. How to force those processes without disturbing the process of construct knowledge is not yet defined.

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[1] CHEMOL is a interdisciplinary project where elementary school students learn science concepts by doing experiments in a chemical laboratory.

[2] Key-word list means a linear list with related words and associations. They are not connected with each other in any traceable way.

[3] The methods have been introduced and used for several other topics with the test persons. One can say that all probands could handle the method of writing a key-word list and creating a Concept Map very well.

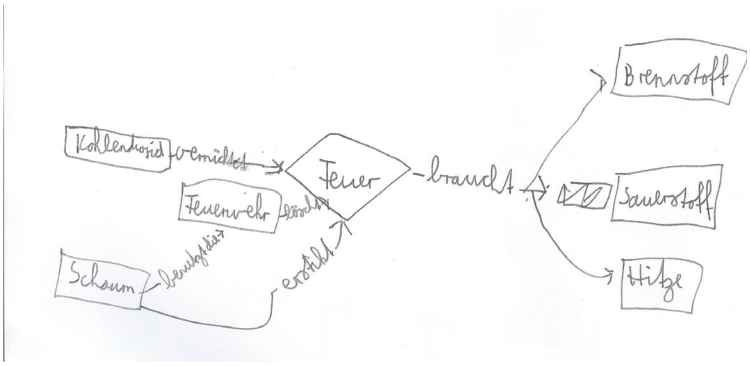

Figure 3: Max Concept Map after intervention

<u>Translation</u>:
Kohlendioxid – Carbondioxide
Vernichtet - extinguishes
Schaum – foam
benutzt – used by
erstickt – chokes
braucht – needs
Brennstoff – burnable material
Sauerstoff – oxigene
Hitze - heat

<u>Scoring</u>:
All: 7
Scientific Concepts: 5
Misconceptions: 0
Crosslink: (7+1) 8

3 Summary and Outlook

Based on the model of Educational Reconstruction an Educational Structuration forms the aim of this research work. Therefore the research object had to be examined from different perspectives. Different perspectives required different evaluation methods which evoked successively from the object itself. Alongside hermeneutic text analysis and inductive content analysis the study required quantitative analyses. To meet the requirements of the research interests a triangulated design (Flick 2004) was necessary and has proofed its value.

The investigation of the students' preconceptions brought up several hints to tie up to. Together with the predictions of the experts the aim is to find guidelines for the work with elementary school students where their special pre-knowledge is to be considered and included into the didactic requirements given by the experts.

The investigation showed that using Concept Mapping as a learning method can have a positive effect on learning science in this specific content, because of the advantages in "usage" of learned concepts as well as the level of networking concepts which showed a positive effect on keeping in mind and understanding of new learned concepts. In this sense, Concept Mapping can be proposed to be an effective learning tool to

- support processes of accumulation of (scientific) concepts. Rote learning can be counteracted through Concept Mapping as concepts must be included meaningfully,
- visualize learning processes in a traceable and transparent way. In the function of being a diagnosis instrument for teachers and researchers, Concept Mapping can be used to show changes or variances at different times of the learning process as well as misconception and the level of severity can be revealed.

The topic *burning and combustion* implies several difficulties for young children. In terms of science content for elementary school students scientific knowledge can not in any case easily been achieved through experiments only but requires the use of abstract model concepts[4] (Harrison et al. 1996) as the experts also advice. The analyses of the students' conceptions showed a big variety of scientific as well as everyday concepts. These concepts are often presented parallel to each other and seem to have no further connection which can be impressively demonstrated through the concept maps of the students. For educational purposes the idea of practical examination through experiments leads to:

a. Give students the possibility to get to know and to use scientific thinking and abstract models of explication,
b. Learn scientific concepts meaningfully and integrate them into existing knowledge structures,
c. Extend the students' experiences with *fire,* which might positively influence their conceptual understanding and emotional access towards *fire*.

The method of Concept Mapping will form the promoter for learning concepts more efficient and therefore more lasting.

[4] These models can be described as rather simple and mainly initiate the micro-macro way of thinking in science.

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